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Understanding Spatio-Temporal Usage Patterns of Cargo Bike Sharing to Foster Market Diffusion

Aurelia Kammerhofer, Florian Pühringer, Leo Kostka, Martin Berger

(Dipl.-Ing. Aurelia Kammerhofer, TU Wien, Research Unit Transportation System Planning, Karlsgasse 11, Vienna, aurelia.kammerhofer@tuwien.ac.at)
(Dipl.-Ing. Florian Pühringer, TU Wien, Research Unit Transportation System Planning, Karlsgasse 11, Vienna, florian.puehringer@tuwien.ac.at)
(Dipl.-Ing. Leo Kostka, TU Wien, Research Unit Transport Planning and Traffic Engineering, Karlsplatz 13. Vienna, leo.kostka@tuwien.ac.at)
(Univ.Prof. Dipl.-Ing. Dr.-Ing. Martin Berger, TU Wien, Research Unit Transportation System Planning, Karlsgasse 11, Vienna, martin.kp.berger@tuwien.ac.at)

1 ABSTRACT

Cargo bikes promote urban resilience as they ensure a local supply of goods, can be used flexibly, are reliable and require low energy, and can even be driven by muscle power. Further, they contribute to socially inclusive mobility. Although driving cargo bikes may require some training, they do not require a driving licence and can be available for different income ranges (e.g. in the form of cargo bike sharing). Thus, they also contribute to health-promoting mobility. Cargo bike sharing is a relevant solution to offer households a practical, environmentally friendly and cheaper mode of transport.

According to public welfare-oriented goals, cargo bike sharing is often provided on behalf of, or with (financial) public sector support, in cooperation with residential developers or based on voluntary work in Austria and Germany. However, peer-to-peer cargo bike sharing offers and host-based sharing systems often do not meet all the criteria attributed to shared mobility services. In order to reach the full potential of cargo bike sharing, a better understanding of spatio-temporal usage patterns is needed to foster a shift towards higher quality service provision, especially regarding tailor-made services for different user groups.

The following article investigates the role of availability and type of service provision by evaluating booking data and spatio-temporal data in three case studies. GPS tracking is rarely used to better understand cargo bike usage, but it reveals further knowledge of the characteristics of users and their spatial usage patterns.

Based on three use cases, usage, users and spatial patterns of cargo bike sharing usage are analysed, the respective potentials are shown, and the added value of spatial data collection is discussed.

Keywords: mobility planning, resilience, spatio-temporal data, sharing, cargo bike

2 INTRODUCTION

The chapter discusses the basics of cargo bike use as part of socially inclusive and resilient mobility, provides an outline of cargo bike sharing systems, and highlights the possibilities of evaluating usage patterns.

2.1 Socially inclusive and resilient mobility

2.1.1 Potentials and fields of use

Existing studies show that cargo bikes are gaining importance in larger cities in the forms of (commercial) cargo transport, for CEP services or privately used for transporting goods and children by private ownership or cargo bike sharing. Up to 51% of all motorised trips in urban areas could be replaced by cargo bikes(FGM-AMOR et al. 2014). This is also reflected in the increase of sales of cargo bikes in Austria by more than 80%(VSSÖ 2021) and Europe by 66%(Statista 2022). However, cargo bikes are rarely seen in smaller cities and rural areas and could still be considered novel transport modes.

2.1.2 Cargo bikes contribute to sustainable and resilient mobility

E-cargo bikes are a sustainable transport mode as they produce nearly no emissions compared to fuel transporters (Fontaine et al. 2021) and reduce traffic noise(Shaheen, Cohen, and Martin 2013). By promoting cargo bikes and cargo bike sharing, municipalities can reduce their dependence on fossil fuels and improve air quality. This primarily benefits people who are vulnerable to health problems (associated with air quality). Cargo bikes as an active mobility mode also promote an active lifestyle and contribute positively to users' physical health.(Kammerhofer et al. 2021; Rabenstein 2015; European Cyclists" Federation 2018; Masterson 2017)

Cargo bikes are less vulnerable to fuel shortages or road closures than motorised vehicles. They can also be used in densely populated urban areas where a lack of space and traffic restrictions can be problematic. By that, cargo bikes help build community resilience by providing alternative transport options, especially in times of crisis or emergency, as they are less affected by traffic congestion and fuel shortages and provide a local supply of goods in the sense of "The City of Short Distances". During high traffic periods, natural disasters or other unforeseen events, cargo bikes can help alleviate traffic congestion and maintain the smooth transport of goods and people. (Randelhoff 2013; Thoma 2014; Kammerhofer et al. 2021)

2.1.3 (E-)Cargo Bikes are socially inclusive

Currently, typical cargo bike users only represent a narrow segment of a diverse population. Cargo bikes, especially in the form of shared mobility offers however, have the potential to enable people of different ages, abilities and financial backgrounds to participate in sustainable transport(Grasso, Barnes, and Chavis 2020; Kammerhofer et al. 2021). Unlike motorised vehicles, cargo bikes are easily accessible and do not require any special skills or a driving licence. They offer an environmentally friendly and cost-effective transport option(Shaheen, Cohen, and Martin 2013) for people who cannot afford or do not want to own a car and who do not have a driver's license. However, by now, cargo bikes are rather used by an exclusive group of citizens (Berger et al. 2019). By promoting cargo bike sharing, municipalities can make their transport infrastructure more inclusive and enable all citizens to get around, regardless of income or mobility.

2.2 Cargo bike sharing

2.2.1 Diffusion and operating models of cargo bike sharing

Cargo bike sharing is a relevant solution to offer a practical, environmentally friendly and cheaper mode of transport to households who do not have access to a car (e.g. affordability, driving rights) or do not want to use a car (e.g. due to environmental concerns). Regarding the potential to further replace privately owned cars, cargo bike sharing contributes to a healthier environment (e.g. by fewer exhaust fumes) (Shaheen, Cohen, and Martin 2013)and frees public space from cars, enabling a redistribution of public spaces and a redesign towards climate-smart public spaces.

Cargo bike sharing schemes can be found in many cities worldwide, especially in urban areas with high cycling infrastructure and a strong demand for sustainable transport options. Germany, the Netherlands, Denmark and many other European countries are pioneers in improving cargo bike sharing services. Concerning the early stage of diffusion, the field of actors and operators is currently rather heterogenous (European Cyclists" Federation 2018). The main actors in cargo bike sharing are often (local) public authorities, non-profit organisations, bicycle cooperatives or private companies. However, only a few bike sharing operators engage in the cargo bike sharing market(European Cyclists" Federation 2018). Recent developments show that private companies struggle with successful operation and feasibility (e.g. GLEAM, SIGO) and that public financial participation is necessary to sustain cargo bike sharing services.

While cargo bike sharing is already widely established in German cities, it is still in its infancy in Austria. For example, the city of Regensburg (approx. 150,000 inhabitants) has approximately the same number of shared cargo bikes as are available in the entire Austria (Radkompetenz Österreich 2023).This might be related to the fact, that, in Austria, most cargo bike sharing offers are peer-to-peer or host-based services.

Peer-to-peer sharing depicts sharing between private persons as clients and providers, who can set user fees independently. In comparison, host-based sharing systems have an organisation which provides the vehicles and sets the terms of use. The vehicles are hosted by small enterprises or private persons, and these hosts are responsible for maintaining the bikes and completing loan processing. In return, they can access vehicles more easily and cheaper. (Dorner 2020) Both peer-2-peer and host-based sharing services are often digitally provided by sharing platforms and in the case of "radverteiler.at", are provided through the same platform.

Most cargo bikes (90 of approximately 130 in total) in Austria are available via the platform „radverteiler.at", which enables peer-to-peer sharing of cargo bikes and is used for host-based sharing systems such as in Graz, St. Pölten or Mattersburg (Radkompetenz Österreich 2023). „radverteiler.at" is not the only initiative to foster peer-to-peer and host-based sharing of cargo bikes in Austria. Other initiatives and platforms inlcude „Grätzlrad" for free cargo bike sharing provided by the city of Vienna, „ListNRide" with mainly fee-based offers and „fairvelo" in the region Vorarlberg.

Public authorities can provide incentives and support for setting up and promoting cargo bike sharing schemes, further to what they provide in general infrastructure for active mobility. Non-profit organisations and bicycle cooperatives are often involved in providing the sharing infrastructure and managing the fleet.

Peer-to-peer cargo bike sharing offers and host-based sharing systems in particular, often do not meet all the criteria attributed to shared mobility services, as they often only have limited rental and availability times and cannot usually be booked or rented independently. Seestadtflotte, for example, was the first fully automated cargo bike sharing worldwide in 2015 (VCÖ 2016), using RFID cards to organise the loaning process.

2.3 Cargo Bike Usage Patterns

2.3.1 Usage Purposes

Cargo bikes are used in both the private and commercial sectors. In the commercial sector, the main areas of use are delivery services (e.g. in the CEP sector). However, hardly any data is available on the use in other types of commercial traffic such as service traffic. Commercial transport accounts for around 49% of journeys made by motorised vehicles in European cities. Commercial traffic distinguishes freight transport ("Güterverkehr" – commercial freight transport, factory traffic) and passenger traffic ("Personenwirtschaftsverkehr" – service traffic, business traffic), of which service traffic accounts for about 20% of commercial traffic. Wrighton and Reiter (2016) estimate that about 50% of service trips could be replaced by cargo bikes.

In the private sector, cargo bike usage covers all areas of everyday life - from leisure rides such as shopping and transporting children as well as transporting larger, bulkier objects and waste disposal trips (e.g. green waste, bulky waste)(Becker and Rudolf 2018; Dorner 2020; Berger, Dorner, and Brugger 2019; Kostka 2020). As shared cargo bikes are mainly used for private purposes, the article concentrates on these in the following sections.

2.3.2 Target Group

As mentioned above, regular cargo bike users are still represented by a narrow field of the population – mainly male persons aged 25-40, with higher levels of formal education(Kostka 2020; Berger, Dorner, and Brugger 2019; Becker and Rudolf 2018; Dorner 2020). However, studies show that by reducing target group specific barriers such as safety perception, infrastructural aspects or family role models, there is a high potential for a more diverse and comprehensive user group(Riggs and Schwartz 2018).

Thus, to reach the full potential of cargo bike sharing, knowledge about and consideration of barriers of non-users is needed. On the other hand, a shift towards higher quality cargo bike sharing services is also needed. Therefore, a better understanding of spatio-temporal usage patterns is needed to foster a shift towards higher quality in the service provision, especially regarding tailor-made services for different user groups.

2.3.3 Spatial Patterns of Cargo Bikes and Cargo Bike Sharing

With the availability of detailed GPS tracks of cargo bike usage, it becomes possible to delve deeper into the spatial patterns associated with their use. This information can reveal the preferred pathways taken by cargo bike users, showcasing the most efficient and convenient routes for different purposes. It can also help identify areas with high demand for cargo bike services, indicating potential areas for infrastructure improvements or service expansions (Romanillos et al. 2016).

GPS data can also be used to identify hotspots such as areas with a high concentration of cargo bike activity. These hotspots could include commercial areas with numerous deliveries, residential neighbourhoods with high cargo bike usage for personal transportation, or specific locations where cargo bikes are utilised for business purposes. Identifying hotspots allows for targeted interventions and infrastructure planning, such as providing dedicated cargo bike parking areas or optimising delivery systems(Li et al. 2020).

In addition, combining GPS tracks with temporal information provides insights into how cargo bike usage varies across different times of the day or days of the week. This analysis helps identify peak usage periods and to better understand temporal variations in spatial patterns. For example, the routes and hotspots may differ during morning and evening rush hours compared to off-peak hours. Such information can be valuable for optimising logistics operations, planning infrastructure, and managing resources effectively(Zhou 2015).

GPS tracks can be used to analyse cargo bike trip origin and destination points of cargo bike trips. This analysis provides valuable information about the origins of cargo bike journeys, such as residential areas or commercial centres, and the destinations, such as specific businesses or delivery points. Understanding the origin-destination patterns helps identify areas with high demand for cargo bike services, supporting urban planners and policymakers in making informed decisions regarding infrastructure development and service provision(Levy, Golani, and Ben-Elia 2019).

By leveraging the detailed GPS tracks of cargo bike usage, research and planning can gain a comprehensive understanding of the spatial patterns associated with these vehicles. This knowledge can guide the development of targeted policies, infrastructure improvements, and service expansion to enhance the integration of cargo bikes into urban transportation systems.

There is a large amount of literature on the spatial patterns of bicycle use (including bike sharing) - but there still needs to be a more explicit focus on cargo bikes in the literature. This paper shows user and usage patterns as well as spatial patterns and discusses the potential of spatial analysis in the context of cargo bike usage.

3 CASE STUDIES

3.1 Methodology

As case studies, cargo bike sharing within „Seestadtflotte“ in aspernSeestadt (Vienna) and „KlimaEntLaster“ in Mattersburg and St. Pölten will be investigated. In aspernSeestadt, an automated cargo bike sharing was implemented and integrated into the bike sharing system Seestadtflotte. Within the research project „KlimaEntLaster“, host-based cargo bike sharing was implemented in small and medium-sized cities such as Mattersburg, accompanied by intensive information and test campaigns. The „KlimaEntLaster“ services were further developed into an automated sharing service, e.g. in Mattersburg and St. Pölten. The higher availability of the cargo bike sharing service led to an enormous rise in bookings in Mattersburg.

Available data sources	**Case Study Mattersburg**	**Case Study St. Pölten**	**Case Study AspernSeestadt**
GPS-Data	No GPS-data available	GPS-tracking (via Radland Niederöstereich) of 380 trips from August 2022 to June 2023	GPS-tracking of 29 trips in May and June 2020 (Kostka 2020)
Reservation Data	Data of 161valid reservations from September 2019 to October 2021 via radverteiler.at	Data of 148valid reservations from June 2022 to June 2023 via radverteiler.at	Data of 670 valid loans in 2019 via SeestadtFlotte
Survey Data	99 valid responses to an on-going online survey in 2020and 2021 in all KlimaEntLasterpilot locations	18 valid responses to an on-going online survey from June 2022 to February 2023 within eTransport 24/7	48 valid responses to an online user survey in spring 2020 (Kostka 2020)

Table 1: Available data sources per Use Case

The spatial analysis involved several steps, which are as follows. Initially, the raw data consisted of multiple GPX files for each use case. These GPX files were imported and merged in ArcGIS Pro to create a comprehensive dataset. Subsequently, the “Reconstruct Tracks” tool was utilised to identify connected trips within the dataset. A split value of 15 minutes was chosen, meaning that if the dwell time at a location exceeded 15 minutes, the track was split. This process helped ensure an accurate representation of individual trips. The resulting trip IDs were then appended to the raw point data through a spatio-temporal join. To enhance the analysis, a map-matching algorithm was employed to snap the GPS data to a street graph (GIP). This step allowed for inferences regarding the utilised infrastructure and road network load. Finally, the “Calculate Motion Statistics” tool was utilised to derive additional information such as speed, duration, and other relevant trip attributes.

3.2 Seestadtflotte

3.2.1 Project Background

“Seestadtflotte” is the station-based bike sharing system in Vienna’s urban development area “aspernSeestadt”. It is part of the mobility concept in aspernSeestadt that focuses on encouraging public transport, active mobility and reducing private motorised traffic. The bike sharing system is open to everyone having a “Seestadtcard” but has a focus on the local population and is not connected to the other Vienna-wide bike sharing-system such as “WienMobil-Rad” and the Vienna-wide host-based cargo bike sharing

“Grätzlrad”. Seestadtflotte currently offers 56 bicycles and e-bikes at eight stations and four e-cargo bikes at one station. Further expansion of the offer is planned in conjunction with the on-going development of aspernSeestadt and according to its own statements, it is the first automatically operated station-based bike sharing that offers e-cargo bikes(Wien 3420 aspern Development AG 2023b). Seestadtflotte was evaluated in the context of a master thesis(Kostka 2020).

3.2.2 Spatial Context

AspernSeestadt is an urban development project located in the 22nd district in the northeast of Vienna, the capital city of Austria. With about 10.000 current residents, the aim is to reach about 25.000 residents and 20.000 employees in aspernSeestadt by the 2030s, making it one of Europe’s largest urban development projects (Wien 3420 aspern Development AG 2023a). Even though there is a subway connection to the city centre, aspernSeestadt is almost its own city in the city of Vienna due to its remote location in the Viennese outskirts. AspernSeestadt was designed as a multifunctional city quarter and is part of Vienna’s smart-city concept, where it is highlighted as a test space for innovative ideas.

3.2.3 Operating Model

Seestadtflotte is operated and maintained by Wien Work, a publicly funded non-profit company that provides jobs for people disadvantaged in the labour market (Knapp 2021). Wien Work has a workshop on site where they can maintain the bikes. Seestadtflotte is financed by the Seestadt mobility fund, fed from charges levied for collective garage operation and construction in exchange for less parking space requirements (Wien 3420 aspern Development AG 2023c). The original idea was that users can ride the bikes 30 minutes for free and have to pay a small amount for longer rentals. However, this is not in place yet, so rentals are still free for at maximum 12 hours.

3.3 Mattersburg

3.3.1 Project Background

In September 2019, three shared cargo bikes were established in Mattersburg, Austria. Cargo bike sharing in Mattersburg was implemented within the research project „KlimaEntLaster (KEL)“ using a sharing platform developed within the research project LARA-Share. KEL aimed to implement cargo bike sharing in small and medium-sized Austrian cities, while developing cooperative, feasible concepts for cargo bike sharing. Thus, the central aspect was to identify barriers to implementation as well as barriers to usage. The KEL project was led by Energy Changes in cooperation with Die Radvokaten, Quadratic, Factum and the TU Wien.

3.3.2 Spatial Context

As a small-sized city of approximately 7.500 inhabitants(Statistik Austria 2022b), Mattersburg is considered a regional centre in Burgenland according to the urban-rural typology(Statistik Austria 2022a). Further, Mattersburg has very good public transport accessibility (Statistik Austria 2023).; with a third of Mattersburg's inhabitants being commuters, primarily working in the metropolitan area of Vienna(Statistik Austria 2020), which is easily accessible by public transport.

The cargo bikes were located according to their hosts; the location of the cargo bikes was changed several times within the runtime of the project „KlimaEntLaster“. Today, only one cargo bike is available in the centre of Mattersburg, 800m walking distance from the central train station. The other two cargo bikes are use in other municipalities in Burgenland.

3.3.3 Operating Model

Within KlimaEntLaster, a host-based sharing system was chosen. This means the municipality and the mobility centre of the county Burgenland financed the cargo bikes, which were then available for free loan at volunteering local businesses or private persons (the hosts). The hosts specify opening hours when other users can book and use the bike. Apart from these opening hours, the cargo bike is fully available to the hosts. The hosts are responsible for checking the cargo bike regularly for safety reasons. Local workshops act as partners for repairs.

In 2020, project partner QUADRATIC developed a solution to provide shared cargo bikes around the clock, independently based on the availability of the hosts. After successfully booking the cargo bike, the user receives a code to unlock the „SmarteVerleihbox“ wall box via SMS. The key for the cargo bike and the charged battery is stored in the box. This wall box was installed for one of the cargo bikes in Mattersburg in May 2020.

The project team set up the sharing service, including legal and technical issues, the search for and training of the hosts, and the allocation of the bikes.

3.4 St. Pölten

3.4.1 Project Background

Since June 2022, a shared cargo bike is offered by Radland Niederösterreich in St. Pölten. The cargo bike was implemented within the project „eTransport 24/7“ together with a smart wall box for 24/7 cargo bike sharing in the city centre of St. Pölten. „eTransport 24/7“ is a follow-up project of „KlimaEntLaster“ aiming to roll out and further test cargo bike sharing based on smart wall boxes for sharing around the clock in small and medium-sized towns and municipalities. QUADRATIC led the project with Die Radvokaten, Energy Changes, Factum and the TU Wien.

3.4.2 Spatial Context

St. Pölten, the capital of Lower Austria, is an urban centre (Statistik Austria 2022a)within close proximity to Vienna and with approximately 56.000 inhabitants(Statistik Austria 2022b). On average, St. Pölten has good public transport access (Statistik Austria 2023) and a high rate of in-commuters (commuting to St. Pölten for work or education) and relatively few out-commuters, most of whom commute to Vienna’s metropolitan area for work or education (Statistik Austria 2020).

The offered cargo bike is located in the historic city centre, within a traffic-calmed area within 400m walking distance of the central train station.

3.4.3 Operating Model

Radland Niederösterreich is hosting the cargo bike. Thus, they are responsible for regular check-ups and customer support. Besides that, the cargo bike can be booked via the platform radverteiler.at and is accessible for free via the „Smarte Verleihbox“.

4 DISCUSSION

4.1 User Patterns – Who uses cargo bikes?

Having a closer look at the question of who the users of the analysed cargo bike sharings are (Figure 1), it becomes clear that in all cases, male users dominate. In Seestadtflotte, the gender ratio appears to be a little more balanced, however, users may share one SeestadtCard or one account on radverteiler.at, so this data maybe inaccurate. Qualitative interviews within KlimaEntLaster showed that male members tend to carry out the booking process in some households, although male and female members both use the cargo bikes. In most cases users are between 25 and 54 years old, whereby the ones in aspernSeestadt and St. Pölten tend to be younger than the ones in Mattersburg. In Mattersburg, compared to the local population, the age group 35-54 is strongly overrepresented amongst users, while persons under 25, are strongly underrepresented. Furthermore, there are only a few users in Mattersburg (28), who use cargo bikes frequently. Finally, it should be noted that the data for Seestadtflotte is based on the online user survey, whereas the data for the KlimaEntLaster projects is based on user and reservation statistics.

Additionally, the number of loans per user is relatively constant between the three cargo bike systems. About 40 % used the cargo bikes only once in the period under review, while another 40% used them two to five times. Very few users loaned cargo bikes more than ten times, and there were hardly any heavy users. Mattersburg’s number of loans per user was slightly higher than in the other systems. The intentions for using the cargo bikes also showed similarities in aspernSeestadt, St. Pölten and Mattersburg. The highest ranked motives for usage were the following: fun for children (as a passenger) and riders (parents); testing a cargo bike; environmental-friendly transport possibility; simple and practical as well as being inexpensive.

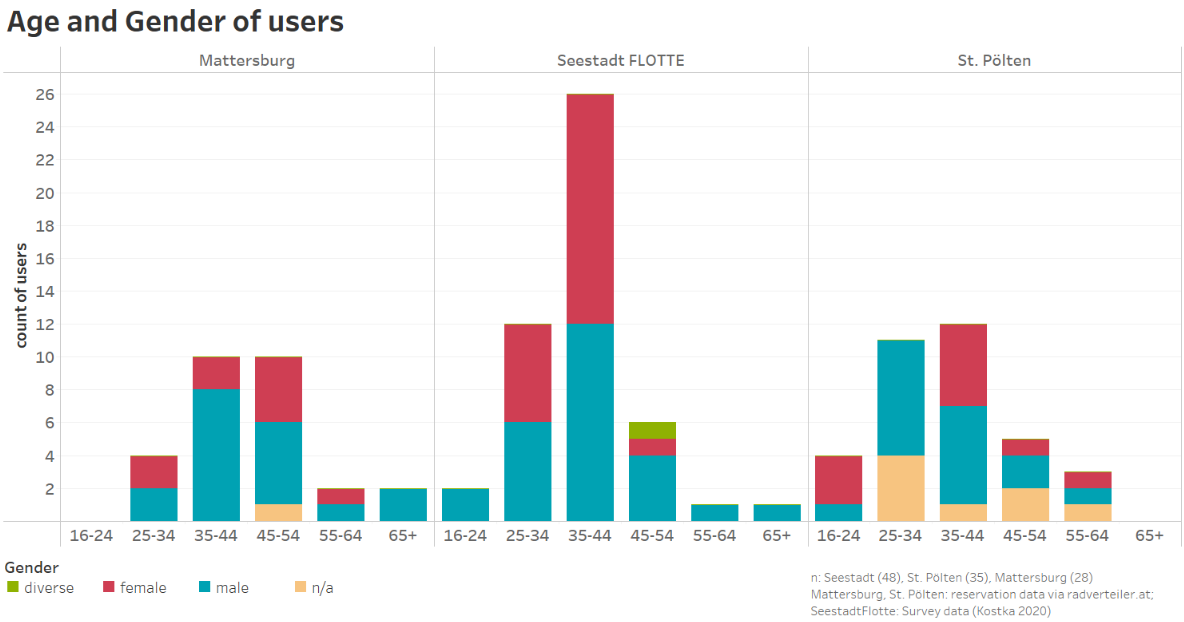

Figure 1: Age and gender of users

4.2 Usage Patterns– How and When are cargo bikes used?

Coming to the usage-related data, we see that most of the bike loan periods begin between 8 am and 8 pm, which is a time span when also host-based services could offer their services. This time span is also related to the purpose of the cargo bike use (see below), where transport of purchases is one of the main issues. Looking at the loans over the course of the day and week in detail, further similarities and differences between the three analysed systems can be revealed. For analysing loans within the course of the week, Fridays were analysed separately from the other working days and weekends, as Friday can be seen neither as a typical working day nor as Weekend. In aspernSeestadt, loans on Fridays and weekends tend to occur earlier than from Monday to Thursday, likely related to users working times. A similar observation can be made in St. Pölten, where users also tend to loan bikes on Fridays earlier than on other days.

On the contrary, some users in St. Pölten reserve bikes also for late Sunday evenings, probably so that they can more easily begin their Monday morning travel from home. Users in Mattersburg behave differently, and the trend to later loans on Fridays/weekends was not observed. While users in Mattersburg took bikes more likely after work too, they also made some loans on working days very early, which was less the case in St. Pölten and rarely so in aspernSeestadt(Figure 2).

Having a look at the loan duration during the course of the week also revealed some interesting aspects. Firstly, loan durations differ significantly between the systems. While users of Seestadtflotte largely loaned the cargo bikes for a very short duration, this was not the case in St. Pölten and Mattersburg.

Even having in mind that the maximum loan duration in Seestadtflotte is only 12h, there are some loans lasting longer. In the other two systems, longer loans are allowed with even whole weekends being possible. It is possible that the very central location of the cargo bikes in aspernSeestadt is a reason for the comparatively short loans because users can easily take a cargo bike again if they need it more times per day. Also, a different purpose of use could be a factor here such as small purchases in the local area and fun rides around the lake for example. While the loan duration in aspernSeestadt is quite constant through the course of the week, this is not the case in St. Pölten, where loans starting on Friday tend to be of longer duration (over the weekend). In Mattersburg, another issue can be observed: While loans on the Weekends last mostly for several hours, loans during the week were either much shorter or longer (more than one day) compared to the other days, whereby longer rentals were rather the case from Monday to Thursday (Figure 3). Reasons for the described usage patterns in Mattersburg and St. Pölten may lie in the bigger spatial expansion of the municipalities compared to aspernSeestadt as an urban neighbourhood of short distances. Further, qualitative and quantitative surveys, as well as GPS-data analysis, reveal longer leisure trips by cargo bike as one of the main usage purposes in Mattersburg and St. Pölten.

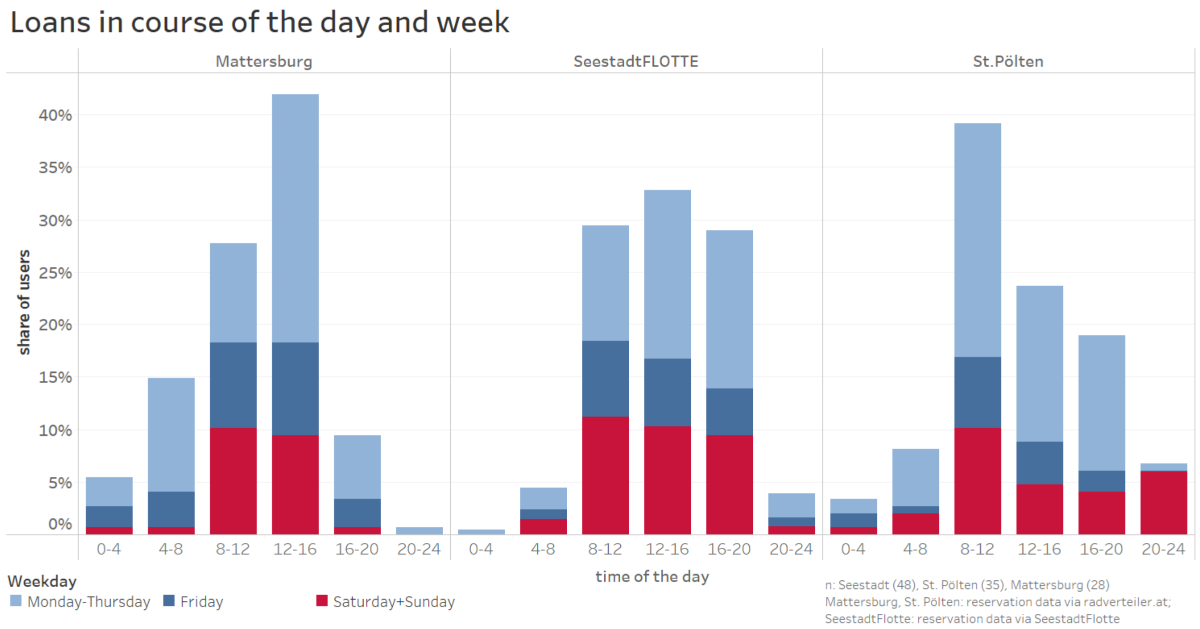

Figure 2: Loans in course of the day and week

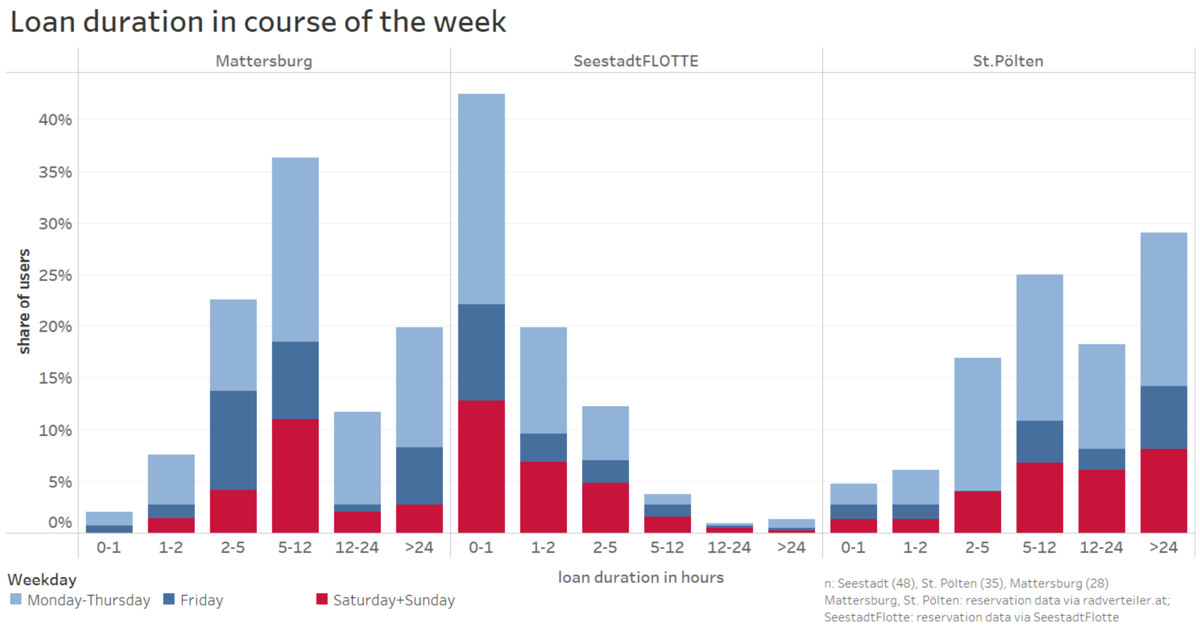

Figure 3: Loan duration in course of the week

In addition to the information presented in the figures, the loan and reservation data analysis revealed that the loans are relatively constant during the week, and there is hardly a difference between the three systems. On Fridays there is a peak in loans in Seestadtflotte and Mattersburg, representing between 15 and 25% of all loans, whereas it is 10-15% on other days. Similarities can also be found regarding transported goods and persons. Cargo bike sharing users primarily transported children, purchases of different kinds, heavy, bulky goods, and equipment for leisure trips to surrounding recreational areas.

4.3 Spatial Patterns – Where are cargo bikes used?

Heat maps are powerful visual representations that provide valuable insights into spatial patterns and distributions based on quantitative data. They are particularly useful in analysing and interpreting the spatial characteristics of various phenomena, including the usage patterns of cargo bikes. Heat maps employ a colour gradient to depict the intensity or density of a particular variable across a geographic area. By visually displaying the concentration and distribution of trips, heat maps enable a first insight into cargo bike usage's spatial dynamics and identify possible key areas for intervention and infrastructure development.

Most trips in St. Pölten are concentrated around the city centre, as the cargo bike station is located at the town hall. This concentration is expected as many trips naturally start and end in this central area. Additionally, the heat map reveals a preference for utilising the dedicated cycling infrastructure along the Traisen River, indicating the importance of well-developed cycling paths in promoting cargo bike usage. Furthermore, the heat map shows that many trips extend beyond the city limits, indicating the potential for cargo bike utilisation in the surrounding, more rural areas, probably for longer leisure trips.

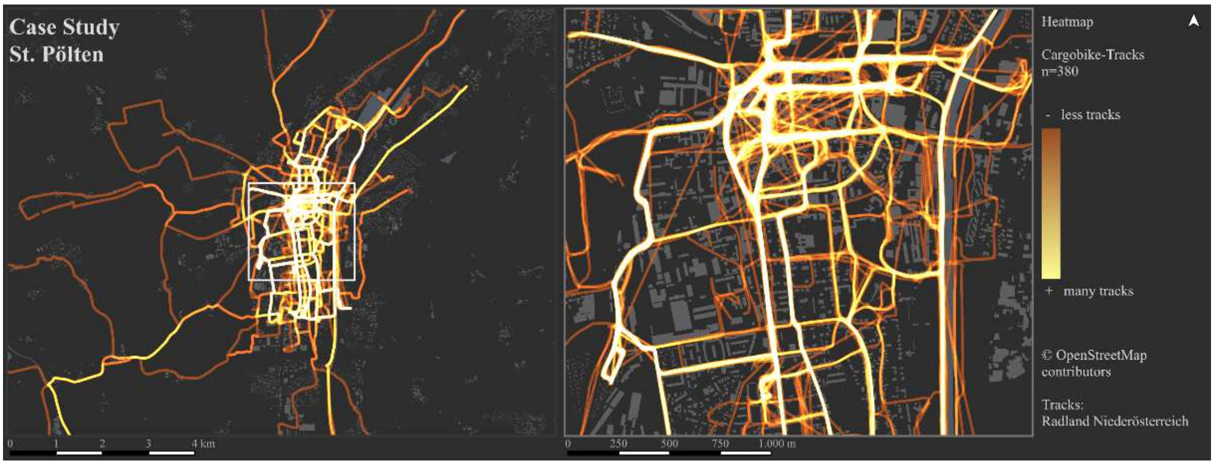

Figure 4: Heat map Case Study St. Pölten.

The heat map of aspernSeestadt illustrates a different spatial pattern characterised by a relatively homogeneous distribution of cargo bike trips. This uniformity can be attributed to the Cargo bike-friendly infrastructure provided throughout aspernSeestadt. The availability of dedicated cycling paths, safe routes, and ample cargo bike parking spaces contributes to a widespread usage pattern. Moreover, the heat map reveals that a significant portion of trips within aspernSeestadt is relatively short, emphasising the suitability of cargo bikes for local trips and the accessibility of amenities within the community, as aspernSeestadt is planned as an urban neighbourhood of short distances. However, it seems that users in aspernSeestadt have not yet recognised the cargo bike for longer leisure trips (e.g., to the surrounding recreational areas).

Figure 5: Heat map Case Study aspern Seestadt

The analysis of speed indicators based on track-level data, considering at least a 15-minute break between each track (see chapter methodology), revealed the following results for the St. Pölten and aspernSeestadt use cases.

These findings indicate notable differences in the average speeds of cargo bike trips between the two locations. In St. Pölten, where the mean and median speeds are higher, suggests a tendency for faster and potentially more direct or longer routes. Conversely, aspernSeestadt, where the mean and median speeds are lower, suggests a preference for slower and possibly more leisurely trips within the neighbourhood.

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Speed indicator	St. Pölten	AspernSeestadt
Mean	17,5 km/h	10,1 km/h
Median	18,0 km/h	10,7 km/h

Table 2: Speed indicators.

The track length indicators provide insights into the variability of trip lengths. St. Pölten's longer mean and median track lengths indicate a tendency for relatively more extensive journeys. This may indicate cargo bikes being employed for purposes such as deliveries, transporting goods to farther destinations, or longer (leisure) commutes. Conversely, aspernSeestadt's shorter mean and median track lengths imply a preference for shorter trips within the neighbourhood or immediate vicinity. This pattern suggests that cargo bikes are primarily used for local mobility needs, such as short-distance errands, commuting within the community, or accessing nearby amenities.

Length indicator	St. Pölten	AspernSeestadt
Mean	3164 m	2127 m
Median	4693 m	3766 m

Table 3: Length indicators.

A map-matching technique was employed to align GPS data of cargo bike trips with the GIP graph edges, a comprehensive dataset capturing detailed information about the road network in Austria. This approach enabled insights into the specific infrastructure utilised by cargo bikes, contingent upon the quality and accuracy of the GIP data. By integrating GPS traces with the GIP-edges, it is possible to identify the routes taken by cargo bikes and to analyse the characteristics of the road segments, intersections, and other relevant features along their paths. This map-matching process can provide a deeper understanding of the spatial patterns in terms of used infrastructure and is a basis for finding bottlenecks.

For the evaluation, the number of map matched cargo bike trips per GIP edge was weighted with the length of the GIP edge – the features of longer edges thus have more weight in the result than those of shorter used edges.

Cars on street allowed/not allowed	St. Pölten	aspernSeestadt
No cars allowed	30,9 %	46,1 %
Cars allowed in one direction (one-way restriction)	7,4 %	6,9 %
Cars allowed	61,7 %	47,0 %

Table 4: Map-matched cargo bike trips and used infrastructure types (cars allowed / not allowed)

In St. Pölten, approximately 30% of the cargo bike trips were recorded on streets where cars were not allowed, 7% of the cargo bike trips occurred on streets with one-way restrictions, and the majority of cargo bike trips, accounting for around 60%, took place on streets where cars were allowed in both directions.

In aspernSeestadt, a higher percentage of cargo bike trips, approximately 46%, were recorded on streets where cars were not allowed. About47% of the cargo bike trips took place on streets where cars were allowed in both directions. These findings suggest that cargo bike users in both St. Pölten and the aspernSeestadt prefer car-free routes, indicating a potential alignment with infrastructure that prioritizes non-motorised modes of transport. The higher proportion of cargo bike trips on car-free streets in aspernSeestadt results from the fact that planning of car-free zones has already been considered in the development plans.

Biking allowed	St. Pölten	aspernSeestadt
No	3,8%	19,4 %
Yes	96,2 %	80,6 %

Table 5: Map-matched cargo bike trips and used infrastructure types (biking allowed / not allowed)

In St. Pölten only a minimal share of the recorded cargo bike trips occurred on streets where biking was not allowed due to biking restrictions. Most cargo bike trips took place on streets where biking was allowed.

In aspernSeestadt, a higher percentage of cargo bike trips occurred on streets where biking was not allowed. These findings highlight both legal and illegal routes taken by cargo bike users, particularly in the aspernSeestadt. This concerns many trips in the parks and green spaces around the lake, where cycling is officially prohibited, but residents still like to use it as a shortcut.

The GIP also includes special information for pedestrian and bicycle traffic, which can subsequently be used for bicycle routing. This information - if complete and correctly recorded - could also be used to assess infrastructure readiness for cargo bikes better.

5 CONCLUSION

This article shows in a rough attempt the relevance of reservation and GPS data analysis for implementing and improving cargo bike sharing systems in order to offer accessible, sustainable and resilient mobility alternatives. However, even further potential lies in the deeper analysis and interconnection of different data as well as in the use of further data such as qualitative and quantitative surveys of users and non-users.

The availability and suitability of cycling infrastructure for cargo bikes remain understudied and further research is needed to understand the specific infrastructure requirements and design considerations that cater to the unique needs of cargo bikes. The „cargo-bikeability“ of urban areas is a crucial aspect to consider when promoting sustainable urban mobility and to that end, different forms of use of cargo bikes tailored to the different needs of various target groups should be considered. This emphasizes the need for further research on infrastructure and the suitability for different cargo bike usage patterns (see e.g. ENTLASTA project).Different user demands should also be considered when designing the operating model. The case studies illustrate that automated lending facilitates access for regular users and for shorter loans, however, an additional contact person could be particularly supportive for first-time users. To exploit the socially inclusive potential of cargo bike sharing, it is necessary to expand outside urban areas and to reach further groups of people. Thus, further research is needed (see e.g. HAUSRAD project).

Spatial data, particularly GPS data analysis, can play a vital role in identifying bottlenecks and challenges faced by cargo bike users. The integration of GPS data provides added value to understanding cargo bike usage patterns, but it is important to consider the complementarity of additional data sources. Supplementing GPS data with other relevant data, such as demographic information, land use data, and transportation demand data, would provide a more comprehensive understanding of the factors influencing cargo bike mobility.

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