Digital Mobility Services for Communities: Flexible boarding points for campus ridesharing

Moritz Gieza[1], Bernhard Kölmel[2], Thomas Schuster [3] and Lukas Waidelich [4]

Abstract: Mobility is still characterized by individual transport. Despite changes in recent years, it still influences infrastructure development and results in car-friendly cities. As a result, traffic congestion reveals weaknesses in efficiency and sustainability of this model. This is exacerbated in metropolitan areas with high growth rates and in areas with below-average public transport services. Besides congestion, emission such as pollution and noise are a major problem. In this article, we give explain how this affects communities in general and transport from and to our university campus particularly. We will examine how digital mobility services can extend public and individual transport. We will explore how digital services can promote intermodal transport and lead to more sustainability in mobility. Within that discussion, we present a ridesharing platform and study its influence on directions to and from our campus.

Keywords: Sustainable mobility, intermodal mobility, public transport, ridesharing, digital mobility service.

Addresses Sustainable Development Goal 11: Sustainable cities and communities

1. Introduction

Increasing individual mobility and growing freight logistics are leading to congestion and pollution. Especially in larger urban and metropolitan areas, citizens suffer from these effects. Cars are responsible for a large proportion of these problems. The slight pandemic-related decline in individual mobility in the past two years is not permanent and has already been reversed in many cases. Especially in industrialized countries, cars still dominate infrastructure development. The resulting issues are evident by increased total travel time relative to a congestion-free situation (congestion level). Especially in evening rush hour traffic, commuting by car is typically congested. The willingness to change remains low so far. This is the case for citizens as well as for urban development. The focus is currently still on road planning and centralized traffic guidance systems, although these have contributed little to improvement until now. The promotion of electric mobility can contribute to the reduction of local emissions. Since only the powertrain is changed,

[1] Hochschule Pforzheim, Tiefenbronner Straße 65, 75175 Pforzheim, moritz.gieza@hs-pforzheim.de
[2] Hochschule Pforzheim, Tiefenbronner Straße 65, 75175 Pforzheim, bernhard.koelmel@hs-pforzheim.de
[3] Hochschule Pforzheim, Tiefenbronner Straße 65, 75175 Pforzheim, thomas.schuster@hs-pforzheim.de, https://orcid.org/0000-0002-9539-1627
[4] Hochschule Pforzheim, Tiefenbronner Straße 65, 75175 Pforzheim, lukas.waidelich@hs-pforzheim.de, https://orcid.org/0000-0003-2602-0942

this has no influence on the congestion situation. In this article, we will focus on individual mobility in general and its impact on traffic congestion in selected urban areas. We will take a closer look at resulting difficulties (emissions, environment, congestion, and citizens) on site. As one solution approach, we discuss digital mobility services and their potential to change mobility behavior. The latter is outlined by a concrete example of an information and ridesharing platform, which is being used at our university. In this paper we will present ideas on how our ridesharing app could be made even more efficient.

The article is structured as follows: Section two presents related work about mobility behavior. This includes both statistical analysis and digital mobility assistants. In the third section, we explain the challenges arising from these findings and relate them to the context of the situation on site. In Section four, we present the current state of our developed information and ridesharing platform. We will highlight its potential for changes in mobility behavior and present suggestions that we believe might increase the app's usage. In the final section, we summarize main findings and provide an outlook.

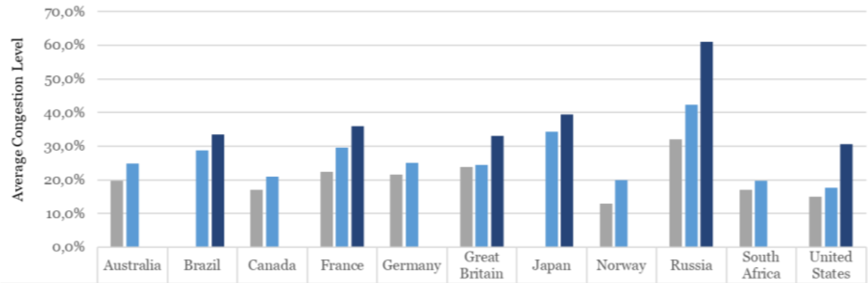
2. Mobility Behavior

In this section, we examine global mobility developments based on current traffic data. Statistical data on traffic development and mobility behavior are used for this purpose. Our attention is on traffic congestion and intermodal mobility behavior. Known approaches to reduce congestion will be presented and challenges will be addressed.
Especially regions with high growth rates (both in terms of population and economy) suffer from traffic congestion. A tempering of congestion levels was observed in and at the beginning of the pandemic. In 2021, global congestion levels were 10% inferior to the previously observed peaks. However, compared to 2020, the situation has already worsened again. Istanbul (Turkey) recorded the highest congestion level at 62%. Bengaluru (India) peak in 2019 (with 72 %), on the other hand, was able to reduce the congestion level (currently still ranked tenth). In London, citizens spent an average of 148 hours per year in traffic jams, in New York 102 [TT22].

In Fig. 1 we display average congestion levels at country level. Congestion level in regions (cities, metropolitan areas) below 800.000 inhabitants is indicated in gray bars, above 8 million it is shown in dark blue and everything in-between in is shown in light blue. The congestion level is a percentage and describes the longer travel time caused by congestion. We derived the data from TomTom's Traffic Index 2021 [TT22] by aggregation of available city data. Compared to the 2019 survey, congestion levels in Europe and North America have decreased by 7 and 14 percent respectively due to the pandemic. The index does not show data for Chinese regions and cities anymore.

Digital transformation of workplaces and new transport services also mitigated the rise in congestion levels [Pi21]. A transfer to home office, the introduction of digital conferencing and flexible working hours led to a global shift in peak traffic times in almost 40% of cities.

In Germany, pre-pandemic levels were already almost reached again by 2021. On average, German drivers were stuck in traffic jams for 40 hours nationwide. INRIX estimates the resulting overall economic costs at € 3.5 billion. That is €371 per driver. Congestion and the associated emissions are a challenge not only for the largest German cities (see Tab. 1). In terms of population, smaller municipalities such as Potsdam or Pforzheim show very high congestion statistics [Pi21].



	Australia	Brazil	Canada	France	Germany	Great Britain	Japan	Norway	Russia	South Africa	United States
<800.000	19,8%	n.a.	17,0%	22,4%	21,5%	23,8%	n.a.	13,0%	32,0%	17,0%	14,9%
>800.000	24,8%	28,8%	21,0%	29,5%	25,0%	24,5%	34,4%	20,0%	42,4%	19,7%	17,6%
>8.000.000	n.a.	33,5%	n.a.	36,0%	n.a.	33,0%	39,5%	n.a.	61,0%	n.a.	30,6%

Fig. 1: Congestion Statistics by Country [TT22]

Congestion and modal split statistics show that the car is still the dominant mode of transport [Ec21]. However, since a couple of years we slowly observe changes. For example, the use of alternative modes of transport (e.g., rail, bicycle, and e-scooters) is increasing. The pandemic has shifted the trend to a certain extent now. Public transport lost considerable attractiveness at times, as commuters began to prefer private means of transport again. New forms of mobility gained in popularity. The use of e-scooters and bicycles is on the rise, often also supported by newly constructed bicycle paths. Many changes can be attributed to the so-called sharing economy and Internet-based mobility services [SW19]. Young people are increasingly using multiple modes of transport. They show a multi- or even intermodal mobility behavior. Multimodal mobility behavior is evident when people switch their main mode of transportation for different trips (e.g., different trips within a week). Intermodal transportation refers to a combination of multiple modes of transportation during a single trip, e.g., a public transportation trip combined with a bicycle or car. Moreover, different modes of transport are used in relation to specific situations (context of the trip and personal preferences) [Ec21, We16]

The reduction in monomodal vehicle use is correlated with age and affinity for Internet services. The introduction of sharing concepts and Internet use are also correlated. Internet-based services show higher growth rates in countries that promote alternative modes of transport [Eu19]. However, it is still not clear today whether there is also a longer-term and causal relationship in this respect. It remains an open question whether these people change their behavior again when they get older or whether they maintain their attitude. Other important influencing factors could be income level and other personal preferences. These typically change with age as well. Individuals make their choice of transport mode depending on factors such as purpose, route, type of trip, origin, and destination of their trip, as well as personal preferences.

Rank	**City**	**Time loss [in hours]**	**Residents [in million]**	**Cost per driver**	**Costs for the Municipality [in million]**
1	Munich	79	~ 1,49	740 €	388 €
2	Berlin	65	~ 3,66	610 €	823 €
3	Hamburg	47	~ 1,85	443 €	291 €
4	Potsdam	46	~ 0,18	428 €	27 €
5	Pforzheim	44	~ 0,12	410 €	18 €
6	Dusseldorf	43	~ 0,62	400 €	88 €
7	Cologne	42	~ 1,08	398 €	152 €
8	Nuremberg	41	~ 0,52	382 €	71 €

Tab. 1: Traffic Congestion & Impacts, Germany [Pi21]

Much work also exists in this area for freight transportation. Optimal routing results in reduced fuel consumption and thus reduced emissions (e.g., carbon dioxide emissions). This includes the idea of rerouting based on the current traffic situation and pre-planning based on the traffic forecast. Routing based on real-time traffic information assumes that traffic congestion can be reduced through intelligent route planning [APL91]. Alternative means of transportation were also proposed [CRS09, GM13]. On the other hand, route optimization is subject to a saturation effect as soon as the information is used by a certain number of users [MC91]. Therefore, routing algorithms are additionally contextualized. For instance through parking models [AP04, FP13] or ad-hoc change of transport modes [CMJ13, GM13]. Besides intelligent routing and information systems, there is another psychological aspect. Users tend to accept suggestions once their preferences are met. These include user interface design, transportation mode (for ad hoc decisions), cost, approximate delay, driver comfort and flexible boarding points.

In terms of new mobility services, Mobility-as-a-Service (MaaS) is proving particularly popular. These are based on Internet and app offerings as well as on the principles of the sharing economy [SW19]. To establish MaaS, public and private providers usually rely on distributed information systems to organize rides. Users usually use the service via apps or web applications. Participation is thus linked to the use and availability of Internet services. The services are mostly subject to usage-based charges (pay-per-use). Costs are usually assessed per trip, according to duration of use and distance, or depending on the current traffic situation. There are currently many different MaaS. To increase attractiveness, many services take personal preferences into account to improve offers and planning. A lot of the services in the sharing space are designed to be unimodal (such as Uber, Didi, Lyft, Lime, Zeus, Bird). In the sharing sector, a basic distinction can be made between ridesharing (private trips) and rideselling (commercial trips) [MS17]. Ridesharing is the provision of rides to private vehicles. The ride can but does not have to be remunerated.

In the case of rideselling, the rides are organized commercially. Rideselling can be subdivided into ridehailing (for individual transportation, e.g., cabs, rental cars, Lyft or Uber Pop) and ridepooling (collective transportation via trip bundling, e.g., Uber Pool, Clever Shuttle or MOIA).

3. Current Status and Challenges

Congestion and resulting delays as well as loads characterize people's everyday lives today. With high growth rates, this situation will continue to worsen. This requires new solutions to improve the overall mobility situation. To reduce congestion levels and the environmental pollution caused by traffic, the following fields of action emerge:

1. Service offerings to meet the demand for mobility
2. Transport infrastructure modernization
3. Reduction of environmental pollution (e.g., particulate matter, carbon dioxide emissions, noise)

The modernization of transportation infrastructure is part of urban or regional transportation planning and management. Different methods aim to improve transportation planning based on predictive analytics and optimization methods [CK19]. The reduction of environmental impacts should be a fundamental goal along all measures. This can be achieved particularly through the choice of propulsion technology, trip avoidance, and route optimization according to ecological criteria.

Consider more closely the opportunities and challenges of deploying MaaS in our city /region and in relation to our university. The city has a population of about 125,000, the surrounding county about 200,000, and the region just over 600,000. The university has about 6,200 students enrolled and 880 people (professors, adjunct professors, and staff) employed. The university has buildings at three different locations in the city and a main campus which about 88% of students primarily attend. It is located on a hillside on the outskirts of the city. A shopping center and leisure facilities (zoo, city forest and restaurants) are located nearby [Ri19]. The approach is mainly by private motorized transport (car, motorcycle) and public transport (bus). There is a direct connection to the main railway station of the city by the public bus. From there, it is possible to get to the surrounding towns and the nearest larger cities that are part of the university's catchment area. There are 524 (319 for students) free parking spaces directly at the university. In addition, 300 parking spaces of the adjoining zoo may also be used. The total capacity is 824 spaces. A highway connection close by favors access by private automobile additionally. At present, a major infrastructure project on the freeway is having a negative impact on congestion. A nearby dorm encourages students to walk or bike to campus as well. However, the strong slope (and a difference of about 100 meters in altitude compared to the city center) and lack of bike lanes prevent many students and staff from using this option for longer commutes.

Preliminary studies of student mobility demands showed transportation peaks as expected. These are in the morning at 8 a.m., at noon at 1 p.m. and in the evening from 5 p.m. onward. During these times, there is insufficient transport capacity in the public transport system. The peak demand occurs on average on Wednesday mornings at 8 a.m. (over 1,800 students). This creates an acute shortage of parking spaces (even outside of peak demand) and results in parking traffic having to move to neighboring residential areas. A lack of parking spaces is a permanent source of dissatisfaction from the perspective of students and residents. The review reveals that about 1,400 students live in the city (daily mobility demand for travel to and from the city about 12,000 person-km (pkm), 1,100 students live outside the city up to 20 km (mobility demand 41,000 pkm/d), and another 750 students live up to 40 km (50,000 pkm/d) away. The remaining students live at distances greater than this. In total, this results in a daily student mobility demand of about 130,000 pkm. 50% of students use cars, 40% use public transport (bus and train), 10% use other means of transport. The measurement of the intensity of use of student cars showed a car occupancy of just under 1.2 persons per car. With the mentioned daily mobility demand and an assumed CO_2 emission of 0.12 kg CO_2/km, the daily CO_2 emission by the students traveling individually is arithmetically 6.5 t/d. The emissions from the mobility of employees and those arriving by public transport or other means of transport must also be added. In a direct comparison, the mobility requirements of the university thus exceed those of the municipal administration (approx. 2500 employees) and presumably also those of the larger companies in the city. The main challenges relate to the following points:

1. Inefficient utilization of vehicles of individual motorized transport (1.2 persons per car).
2. Increased congestion (the city is generally one of the most congested in Germany) and the university's contribution to this.
3. High emission levels due to daily directions (CO_2, particulate matter, and noise)
4. Conflicts caused by parking in the surrounding area.
5. Issues created by searching for parking (cruising).
6. Return to classroom teaching increases pressure on issues 1- 5.

4. Community Service Development

The university has defined sustainability goals. This includes a 50% reduction in total emissions by 2030. Regarding traffic and directions, the following measures are intended to contribute to this objective:

1. Development of a new mobility culture including innovative mobility offers.
2. Reduction of individual transport via e.g., bundling/sharing approaches.

3. Reduction of emissions through zero-emission drives in individual and public transport, e.g., through electromobility.
4. Avoiding trips by offering a modern range of services.

We conducted three steps to prepare and develop these measures. First, an investigation of the current approach situation was carried out (see above). Then, alternative arrival concepts were investigated and designed. Finally, the design and implementation of MaaS was started by development of a ridesharing platform. The ridesharing platform was deployed in winter semester 2021 but was only used briefly (over a two-week period) due to the pandemic and the resulting online classes. An overview of the ridesharing platform is visualized inFig. 2.

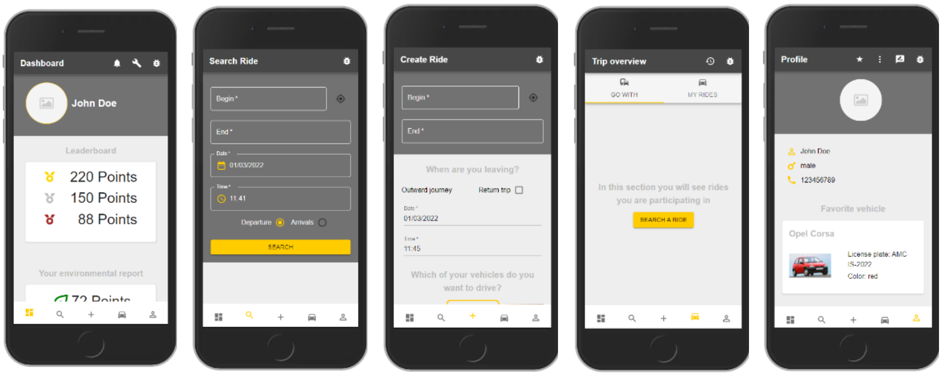


Fig. 2: Ridesharing platform user interface

The ridesharing platform allows users to search for and offer rides. To increase the possibility of user participation, the associated app is implemented as a progressive web app. This makes it possible to use it on any smartphone. No app store is required, users simply access the app via a browser. In addition, the use of the app is also completely unrestricted on any tablet or desktop PC. The app consists of five main areas: 1) Home; 2) Ride search; 3) Ride offer; 4) Ride overview; 5) User profile. The areas are designed according to common usability criteria and partially feature a tile layout. A dashboard serves as the home, presenting the user with currently relevant information (area 1). In addition to the information, the dashboard implements a gamification concept. Users can see how much carbon has been avoided and who has currently contributed the most. This allows students and staff to receive vouchers for the cafeteria. The second area (2) provides a search dialog to find offered rides and to request rides. Once a user has requested a ride, the provider can confirm or decline it. In case of agreement on the rideshare, both sides receive ride-relevant information (e.g., the rider receives information about the vehicle). The third space (area 3) is used for the administration of the trip offers. Ride offers can be created as one-time or regular rides. An overview of pending and past rides is provided in the fourth area (4). Users see which rides they are offering, who is riding with them or where they are riding themselves, and the ride's status. The last area serves to manage the user profile (area 5). Users who want to offer rides themselves must also enter a vehicle. In addition, ratings received from other users for rides are viewed here. Feedback can be submitted after a ride has been completed and, as well as a points system, also allows a comment to be entered. A review can be submitted anonymously or personalized.

The ridesharing platform was well received after a promotional campaign (see Fig. 3). As a result, 764 users have registered in the system in a short period of time. Users can simply use their university user account for this purpose. In the two weeks leading up to the renewed pandemic lockdown, 303 trips were scheduled with an average trip duration of 28 min and 6 seconds (variance: 5 minutes and 17 seconds, standard deviation: 17 minutes and 50 seconds). In line with expectations, most of the trips were offered on Wednesdays. The exact distribution on the weekdays was: Monday: 53, Tuesday: 64, Wednesday: 87, Thursday: 51, Friday: 33, Saturday: 4, and Sunday: 11. Due to the planned trips and results in 0.12 kg CO_2/km there is already a saving of about 1.1 t CO_2.

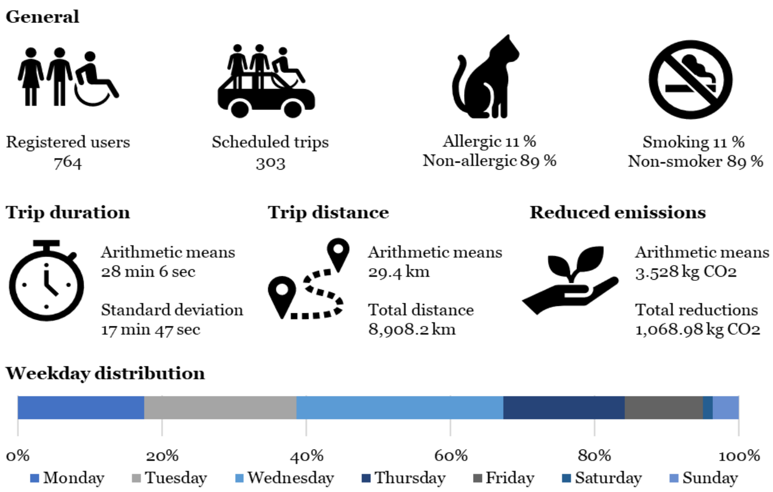


Fig. 3: Ridesharing platform usage patterns

Since the initial deployment of the ridesharing platform experienced a very positive user response, its planned for further and extended use upcoming terms. By returning to classroom teaching, we expect increased and continuous use. This will make a sustainable contribution to the university's emissions goals. The short evaluation period has already attracted attention from outside the university. City officials intend to offer the platform to city employees as well. A corresponding project has been launched.

We see a lot of potential to evolve the state of the ridesharing platform further. The ridesharing platform is aimed at bundling travel needs to the university in a flexible manner, enabling alternatives and improving efficiency (vehicle utilization, congestion situation). Dynamic boarding points are to be generated automatically and integrated into the routing of ridesharing trips. By using the generated entry points, the existing platform shall be enhanced by adaptive route selection. Thus, efficiency and attractiveness of routes and ridesharing shall be increased. To this end, the following points are to be addressed in the future: First, the improvement of the ridesharing application including validation through A/B testing with users. Second, the analysis of the access routes and identification of the main constraints. Third, the identification, generation and testing of dynamic boarding points. Fourth, to improve traffic planning and routing in the application.

5. Conclusion

Traffic development and congestion is still an enormous problem worldwide. This has a negative impact on the environment and on individuals. Problems also arise economically, e.g., due to time losses and stress. Numerous research projects and studies are addressing the problem and aim to reduce traffic congestion. The usage of ubiquitous MaaS can be a promising approach. MaaS provide an opportunity to explore and use alternatives, especially to motorized individual transport. Information when to use which service properly is an important factor in achieving behavioral changes. In many cases, awareness of alternative mobility services is almost as important as their availability.

Our ridesharing platform demonstrated that digital planning and collaboration amongst users can create a considerable amount of interest and behavioral changes. The evaluation over a longer period was not yet possible due to the pandemic. Hence, this represents a consistent next step in our research. It will include evaluating the success of the gamification aspects of the application. Key questions will be which factors will create long lasting changes and how to make ridesharing experience increasingly sustainable.

Furthermore, we want to supplement the application with additional services. We intend further development of intelligent route planning, so that both routes can be optimized according to ecological criteria and intermediate stops can be planned as optimal as possible. The latter involves individual travel routes of platform users as well as traffic of user people (who should not be impacted by stops and onboarding of ridesharing users). Finally, the application will in future draw greater attention to intermodal route chains.

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