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Instruments and effects of integrated mobility concepts—the case of a new housing project in Berlin, Germany

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Abstract

In new residential neighborhoods, planners often implement mobility concepts consisting of various measures and instruments, which intend to serve as alternatives for private cars and thus limit the negative external effects of motorized transport. However, there is a lack of studies regarding the impacts of such concepts. Accordingly, we analyze which actual effects mobility measures have on transport and land consumption. Investigating a newly developed low-car neighborhood with 361 households in Berlin, Germany, we surveyed the residents (45 survey participants) and simulated transport. Our results show that planning ideal and lived reality differ—new residents bring more cars than expected and planning intentions differ from what residents want and use. Only strong measures may change mobility behavior but better information and mobility management could help to increase awareness, acceptance and use of new mobility options.

Keywords Mobility concept, New residential area, Survey, Travel demand modeling, Microscopic simulation, Low-car neighborhood

1 Introduction

Striving for sustainable transport solutions, more and more political actors include measures supporting mobility services as potential alternatives to using private cars in their strategy for the development of new residential areas. Thereby they intend to reduce traffic, land consumption, emissions and hence improve air quality and increase sense of place [16]. Research shows that there is not the one-and-only-solution to achieve this. Rather, it requires a mix of different measures and a combination of push and pull instruments that either constrain the use of cars or provide additional offers. So-called integrated mobility concepts combine a diverse range of measures related to urban development and transport at the neighborhood-level and thereby serve as an instrument to achieve sustainable mobility (see e.g. [11]). Successfully implementing such concepts in the context of car-free cities requires their constant evaluation [17]. To our knowledge, studies in the field (e.g. [3, 5, 7, 8, 15–19]) mainly investigated the impact of single measures on traffic or environment but not of a combination and for different indicators associated with sustainable transport. What is more, only few authors compared what is planned and what is actually lived [20]. The purpose of this research is thus to find out whether and how such concepts and related actions can actually contribute to a more sustainable mobility. Important indicators to measure the effects include e.g.: car ownership/motorization rate, modal split (used e.g. by [8]) and space used for transport, e.g. in terms of the number of cars in the area or land used for parking. More qualitatively, Bamberg [4] introduced a scale that measures how much people are willing to change their car use—from a) reluctance to

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b) having no choice to c) the intention of changing to d) planning a change to e) realizing it in already rather using other options and f) having no car. Some of these effects are determined by transport models while others are the result of surveys.

Klein et al. [13] analyzed the knowledge and acceptance of mobility options as well as the mobility behavior of residents in a new housing area in Darmstadt, Germany, surveying over 1000 households. This development is comparable to our case study (see Sect. 2.1) in terms of location and measures and was also developed and investigated at the same time. However, at the time of the study, the development was much larger regarding the number of households (361 in WATERKANT Berlin). The survey mainly included statements that respondents were asked to rate in terms of how much they agree to them. The authors found that car ownership and car use significantly decreased while public transport and car sharing were used much more than before the time of moving.

In a previous study [11], by reviewing different car-free and low-car projects and by expert assessment, we identified measures which in their cases contributed to achieving previously set goals and eventually categorized them into seven groups,among them are: efficient public transport, qualitative walking and cycling environments, parking management and sharing offers, information of residents and a combination of mobility offers.

Addressing some of these categories, in this paper, we review mobility measures and their combination applying two methods. Investigating a newly developed neighborhood in Berlin, Germany, we used a survey of residents and transport simulations to find out: Which measures exist that can help to be mobile without the private car? What impact do mobility concepts have on car trips and land consumption? Finally, which combination of measures lead to less traffic and a higher use of more sustainable means of transport? The paper will first describe the case study and the methodology for both the survey and its analysis, and the simulation including a description of scenarios and the modeling approach. We then turn to the results of the survey and the simulations and finally discuss the results and line out the main conclusions and implications for policy makers and future work.

2 Methodology

2.1 Overview and study area

Establishing new mobility routines at the new place of residence takes some time. As short time frames in research projects do not allow to directly observe changes over a long time, a multi-method approach is applied in this research. In our case study, we investigate mobility in the newly constructed area WATERKANT Berlin. For analyzing the effects, first, a quantitative survey identified the potential individual benefits of existing and hypothetical mobility services and offers in the study area. Second, a microscopic travel demand and flow modeling approach tested different combinations of measures in three scenarios and evaluated the resulting changes of modal split and land consumption. The two methods are connected. The models particularly test the effects of those measures on transport that were rated the highest in the survey. These are then included in the scenarios. However, the transport model cannot test all the measures that were used in the survey since some are just not represented by the model and for others there is not enough data. As an example, the measure *displays for real time information* is not possible to operationalize in the travel demand model. Furthermore, the demographic structure regarding age, household size, income and car ownership is used to build a synthetic population for the study area (see Sect. 2.3).

The study area WATERKANT Berlin (area C in Fig. 1) is a new large residential development. In total, it is planned that over 2500 households will be living there by 2026. At the time of this study, one part of the development was finished, featuring 361 housing units. The study area is located in the outer city of Berlin in the district of Spandau and on a peninsula. The distance between the area and the next main public transport station (subway U Haselhorst) is over two kilometers and people would have to walk about 30 min to get there. A bus serves part of the area at a headway of 5 min during daytime. From other bus stops which are closer to many of the homes, a bus leaves every 10 min. Before construction started, the area was of rather low density of about 200 persons per hectare. With the new buildings, density has increased to more than 350 persons per hectare [2].

The mobility concept of the study area is based on a comparably low maximum number of parking spaces. Developers are allowed to construct only 0.4 car parking spaces per resident. The first block constructed features 90 spaces in an underground parking garage. Together with the few parking spots on-street, this equals to space for about 0.3 cars per household. This required the implementation of several other measures, such as a mobility station (asterisk in Fig. 1) with different sharing vehicles, among them electric kick scooters and flexible and station-based car sharing. The station is accessible by everyone.

The development itself further features secure and sheltered bicycle garages for the residents which they can rent, as well as a parking space in the underground garage. The development of the first blocks was planned pedestrian-friendly with spots to play and sit, and greenery. Bus headways were increased for one line shortly

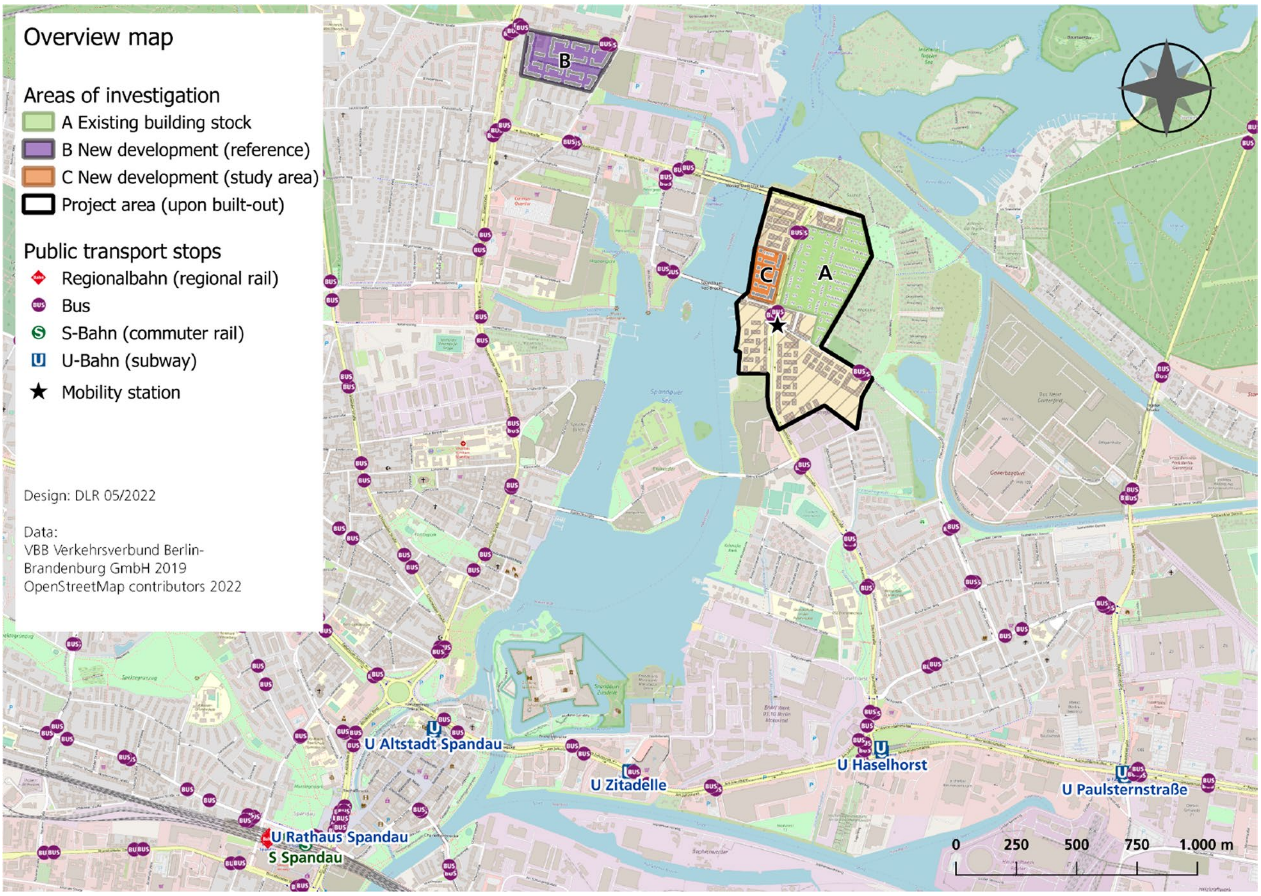

Fig. 1 Overview of the area of investigation *Source*: DLR, 2022

after the first residents had moved there. Information about the mobility concept including offers and services were provided in December 2020 after the opening of the mobility station.

2.2 Survey of residents

This article refers to a survey among the residents of the study area (C), conducted in summer 2021. At this time, the residential neighborhood was still under construction and 361 households were living in the study area. The aim of the survey was to gain information on the population structure and mobility options in a new residential area, and to learn about the residents' mobility behavior and preferences as well as their opinions and usage of new mobility offers and services. Questionnaires were inserted into mail boxes of all households in this area and in two reference areas (see Fig. 1), one previously existing neighborhood constructed between 2002 and 2014 adjacent to WATERKANT Berlin (A), and one new development with similar structure and access but with no mobility concept planned for it (B), earlier (2019 and 2020). The survey could be completed on paper or online by one individual per household. A reminder letter was distributed after three weeks. 45 individuals representing 45 out of 350 addressed households in the study area answered the survey in 2021, resulting in a response rate of 12.8%. The questionnaire covered a wide range of questions on the topics of housing and living environment, mobility in everyday life (e.g. means of transport use, mobility behavior at the current situation and before the last move), orders and delivery options, new mobility offers and attitudes, and household information including socio-demographic information for all household members. Both, single-choice and multiple-choice questions as well as one open question on requested mobility offers and services were asked. Specifically, it also included a question where people were asked to rank the individual utility of new services and how much it helps them to move without their private car on a scale from 1 (none/not at all) to 5 (high/a lot). Another question addressed the readiness to change the automobile use following a socio-psychological approach asking participants to assign their own behavior to one of six phases by choosing one statement [4]. Furthermore, we included questions on the level of knowledge of the mobility concept since we assume that this is fundamental for their use, and the self-reported actual use of existing mobility options. For this article, data were analyzed using descriptive and bi-variate statistical methods in SPSS software.

2.3 Modeling approach

The daily mobility of a simulated population is usually modelled by travel demand models. The complex situation of the study area described in section a makes it difficult to evaluate the effects of the different measures of the mobility concepts individually. The mobility is strongly depending on the demographic structure, the available modes of transport and the accessibility of nearby destinations. Therefore, we decided to run a travel demand model, which takes all these different aspects into account. In this case, we used the agent-based travel demand model TAPAS (TAPAS—Travel Activity Pattern Simulation) [21] and the traffic flow simulation software SUMO (Eclipse SUMO—Simulation of Urban Mobility) [6, 12] This approach has been used in several studies regarding infrastructure measures [14, 22] as well as impact assessment [10].

TAPAS simulates the activity patterns for each person in a synthetic population. It searches for matching locations to perform the activities, considering accessibility with respect to the current location via the available modes, and the capacity of the destination. Finally, it selects a mode of transport and performs several feasibility checks. Cars are distributed on a household level and double booking of the same car for the same timeslot is prohibited. In this work, we simulate the whole city of Berlin, Germany, because this way it is possible to consider commuting and capacity constraints due to people living outside the region. The result of TAPAS is a detailed list of location-changes for each scenario consisting of person-id, activity type, start time, end time, start location, end location, mode of transport, duration of activity and, in case of a car trip, the ID of the used car.

This information is fed into the traffic simulation SUMO, which calculates routes and takes the capacity of roads and public transport into account and adds waiting times to the travel time in case of full buses or traffic jams. A detailed description of the modeling approach can be found in Heinrichs et al. [12].

A variety of input data is necessary to simulate different scenarios in TAPAS, for example, activity locations, a synthetic population or travel time matrices. A synthetic microscopic population was created with the tool SYNTHESIZER [22], based on the survey results and construction plans. Because simulations needed to start before the first residents moved to the study area, we extracted the social structure of the reference area from the survey of reference area B in 2019 and extrapolated it to the new neighborhood. The car ownership for the study area was set to 0.7 cars per household, assuming that people do not consider the available parking spaces when moving there.

2.4 Scenarios

We defined three different scenarios (Table 1) and estimated the resulting changes in modal split as well as land consumption using the previously mentioned programs TAPAS and SUMO.

Scenario 1 simulated measures that have actually been implemented. These measures include a mobility station providing e-scooters, bike sharing and an information monitor. Furthermore, protected bike stands were provided at the building and at the nearest subway-station, which included a returning point for bike sharing as well. The frequencies of the two bus lines were increased to 5 min in the main service time.

Scenario 2 additionally introduced better infrastructure for cyclists in form of a dedicated bike lane and optimized traffic lights, which result in a safer and faster ride. Additionally, an extra bus lane was introduced to minimize the waiting times in traffic jams. Finally, to reduce parking pressure in the area, a parking fee of 1€/h for external cars was implemented.

Table 1 Summary of the characteristics of the three scenarios

	Scenario 1	Scenario 2	Scenario 3
Public transport	New bus line	+ Bus lane	+ Stops at additional urban rail track connecting with the city center
Bike	Protected bike stands in WATERKANT and in closest subway station (one-minute reduction of travel time)	+ Cross-free bike lane to closest subway station (additional one-minute reduction of travel time)	+ Bike highway (bike speed increased by 2 km/h)
Car		+ Parking fee of 1 € per hour for non-residents	+ Reduction of residential parking permits in study area (0.5 cars per household)
Further measures	Mobility station with car sharing, e-scooters and an information monitor	cf. Scenario 1	cf. Senario 1

Scenario 3 extended the second scenario by additional measures. First, it reduced the number of residential parking permits in the area to 0.5 cars per household (reduction of 440 cars)—this number was the assumption during the official planning phase. Second, public transport was enhanced by including stops of a reactivated additional urban railway track called 'Siemensbahn', which is directly connected to the circular track surrounding the inner city of Berlin. Finally, the interregional bike network forming a separate bike highway net was introduced, according to the municipal plans of the city and an additional direct connection from this network to the area was implemented.

3 Results

3.1 Residents' perspective

Based on the answers of the 45 participants and compared to the surrounding district of Spandau, persons in these households were much younger and households slightly larger (average 2.2 persons per household as compared to 1.9 for Spandau [2]). As is typical for many new residential developments at the edges of cities, the main groups were young families and couples. 40% of the persons in these households were younger than 30 years. However, according to official statistics, more than half of the persons living in the neighborhood belong to that age group [1]. Hence, young families in particular were underrepresented in the survey. The largest differences occurred in the groups 0–5 (5% in the survey and 17% according to official numbers) and 30–44 (40%, and 31% respectively). This should be taken into consideration when interpreting the results.

These young couples and families also often brought their own car regardless whether they knew about the mobility concept. Participating households had about 0.9 cars per household while one quarter had no car at all which is much lower than in Berlin (43%, [9]). One third of the surveyed residents said that they had no bike which is much higher than the average. A bit more than half of them possessed a monthly pass for public transit—which is on average. Finally, one third out of 39 respondents stated that they were member of a flexible car sharing provider and half of them were member of mobility sharing in general. This is twice the share in both reference areas. The private car, however, was still the main means of transport after movement by foot, but the majority of respondents used more than one mobility option. 31% drove frequently their private car, while 36% combined it with transit, bike, or both. One in six persons used bike and transit, 11% only public transport and 7% only the bike. The car, however, was used by fewer persons on a daily basis than transit.

The findings show that parking is a huge problem. More than half of the respondents parked their car on-street. The participants owned 0.9 cars per household, which was much higher than the amount of parking provided. This seems to also affect the residents—more than two third of the surveyed persons were dissatisfied with the parking situation in the neighborhood. Accordingly, land consumption by parking was the most criticized problem among all transport-induced effects, including such as emissions, congestion and noise—46% said that land consumption by parking made them feel very much disturbed.

Since the mobility concept intends to provide opportunities for moving without a private car, we also wanted to know how much willing participants were to change their car use. Here, one in four persons said that they did not own a car, 14% already used other modes as often as possible, 11% did not know how to move without their own car, but half of all the persons having answered this question did not see the possibility or need to change their behavior. Thus, the question arises how much the mobility offers would actually help residents to reduce their car use. Regarding potential mobility-related measures, respondents found an extra bus lane for rapid transit, stores for everyday needs in walking proximity and an open parcel locker the most useful. However, sharing offers were considered as beneficial only by very few respondents.

Two third of the residents had heard of the mobility concept and half of those knew it well. Although the development was claimed to be 'innovative' regarding mobility options and services, only few had moved there because of that: three quarter of the persons knowing the concept (n = 29) did not consider it in their location decision. Still, one third thought it was somewhat helpful to move without their private car. Results regarding the actual use of new mobility offers show that some services such as the bicycle garage (18% of respondents), electric kick scooter sharing (11%), the mobility station (9%), and even flexible car sharing (7%) have been used at least on a monthly basis or more often.

The results from the survey imply that mobility services that planners intend as alternatives for the residents might not be accepted by all of them and this in turn differs from the actual use. Simulations provide further evidence on which measures should be implemented from a sustainability point of view.

3.2 Simulation studies

Figure 2 depicts the modal split for scenarios 1 through 3. While measures implemented in scenarios 1 and 2 (such as sharing services at a mobility station, an extra bus lane, and better bicycle infrastructure) do not appear

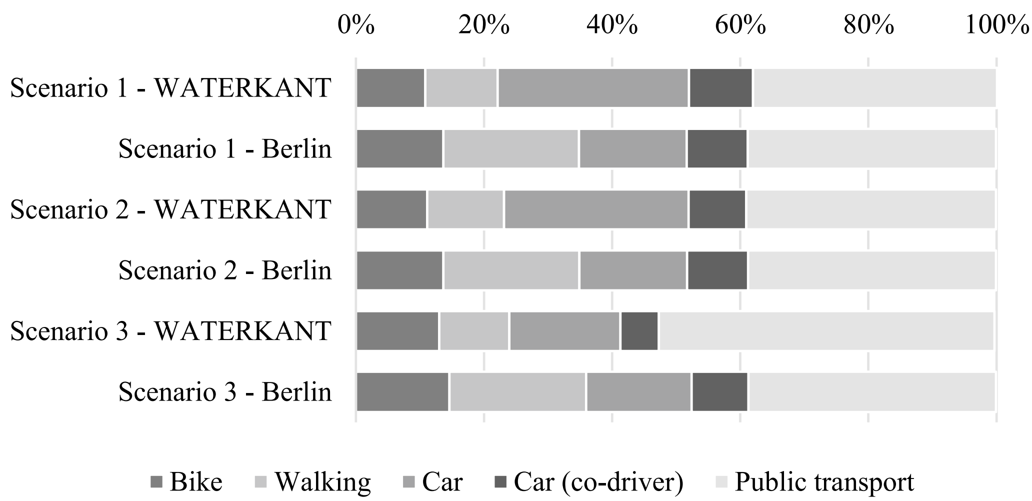

Fig. 2 Modal split for the three scenarios differentiated by study area

to have had any effect on the modal split, a clear change in mode choice can be seen for scenario 3, where public transport and bicycle infrastructure were significantly improved and parking was further limited. The number of car sharing trips is negligible in all scenarios and is therefore not shown in the chart. This shows that car sharing is not intended for everyday use. The modal share of the active modes (walking and cycling) is comparable in all scenarios. The modal share for car and public transport, however, differs in the last scenario, as compared to scenarios 1 and 2. The reactivation of the Siemensbahn in scenario 3 has the effect of shifting the modal split in favor of public transport (52% in scenario 3 versus 38% and 39% in scenario 1 and 2, respectively) while reducing car use (17% versus 30% and 29%, respectively) and also slightly reducing bicycle use (11% in scenario 2, and 13% in scenario 1). A reduction in car ownership further contributes to this outcome. However, the modal split for the city as a whole (not only for the residents of the new residential area) shows a significantly higher share for walking and a lower one for cars compared to residents of the study area.

The average trip lengths and travel times by mode of transport are presented in Table 2. In terms of trip lengths, the differences between the scenarios are minimal for the residents of the study area. The general average travel distance in all scenarios is more than 1 km longer for the residents of the study area compared to the city-wide values. For example, looking at the differences by activity type, a child living in WATERKANT needs almost 10 km to reach the primary school, while the average value for Berlin is about half of that. This would also explain the general high use of transport modes for longer distances, namely car (co-driver) and public transport. With regard to travel times, the new bus lane in scenario 2 and the urban train in scenario 3 seem to have shortened the time spent in public transport. However, from traffic flow simulations, we could see that an extra bus lane does not actually reduce motorized traffic and reduces travel times only marginally. The average travel times for the city as a whole are in all cases slightly shorter than in the study area.

Another important topic we addressed is land consumption. Figure 3 presents the parking utilization at

Table 2 Average trip distance and duration for the residents of the study area and the city

Mode of transport	Average trip length (km)			Average trip duration (minutes)		
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Bike	6.8|*5.7*	6.7|*5.7*	6.5|*5.9*	37.7|*32.1*	37.3|*32.1*	34.5|*31.7*
Walking	2.3|*1.8*	2.3|*1.9*	2.3|*1.9*	31.6|*27.2*	31.9|*27.2*	32.2|*28.3*
Car	10.3|*9.2*	10.6|*9.2*	10.5|*9.2*	33.7|*31.2*	34.2|*31.2*	34.1|*31.1*
Car (co-driver)	11.1|*9.9*	11.1|*9.9*	11.2|*9.7*	34.9|*32.6*	35.3|*32.6*	35.6|*32.2*
Public transport	14.0|*12.7*	13.8|*12.7*	13.5|*12.5*	59.2|*54.1*	57.8|*54.1*	55.4|*53.3*

Trip distance in kilometers and trip duration in minutes. Values for the residents of the study area (on the left) and for the whole city (in italics, on the right)

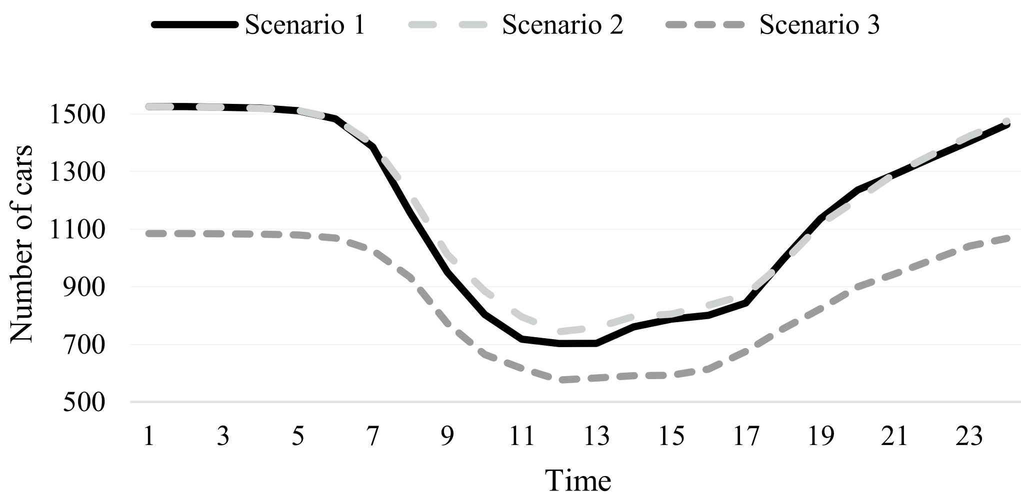

Fig. 3 Parking utilization in the study area in the course of a day differentiated by scenario

the study area during a day for the three scenarios. The differences between the values in scenarios 1 and 2 and those of scenario 3 vary with the number of cars assigned to the new residents: 0.7 cars/household in the first two scenarios and 0.5 in the latter. The chart shows a reduction of parked cars during typical working hours, which implies that the main land use of the study area is residential. For this reason, the introduction of a parking fee in scenario 2 does not show any reduction in the number of parked cars.

4 Discussion, conclusion and future work

Results for WATERKANT Berlin show that planning ideal and lived reality often differ [20]. What residents see as useful for their own mobility does not have to correspond to what actually has an impact. The extra bus lane—a measure highly ranked by residents—did not significantly reduce travel times in the simulation. While the new residential area was planned as low-car, more new residents in the case study brought their own car (0.9 cars per household) than expected (0.4) which is similar to a comparable new development in Darmstadt, Germany [13]. Here, residents also had 0.9 cars after moving, while parking was available for only 0.65 cars per household. This stresses even more the importance to organize parking and provide attractive alternatives. An efficient and high-capacity public transport should be the backbone of any mobility concept. As our results indicate, improvements such as extra bus lanes or a new railway station are highly demanded by residents and may also result in reduced motorized traffic. However, our simulations show that a significant change can only be achieved by extensive interventions. Only scenario 3—where infrastructure was greatly improved and car-use restrained—brought about a significant reduction in car trips and an increase in active modes including public transport, respectively. Implementing a mobility station and sharing services alone did neither result in a significant use of alternatives nor did it reduce car use. The study in Darmstadt, however, found stronger effects of implemented measures on changes in actual mobility behavior [13]. We also saw that traveled distances are long on average and thus require according modes. Locating stores closer to residents, as requested often in the survey, could avoid such trips (by the time of publication, a super market had opened in the study area). Finally, fewer vehicles due to fewer permits also mean a reduction of parking space needed in the investigated area corresponding to 5280 m^2 (assuming 12 m^2 land consumption per parked car)—this is approximately the size of a small soccer field or park.

For planners and developers, it is important to have the same goal in mind and really enforce parking rules and car ownership limitations. Results from the simulations corroborate previous findings that only push and pull measures together achieve a shift in the system resulting in less traffic and land consumption [17]. The comparatively low information level found for the concept at WATERKANT Berlin provides an opportunity—it is important to inform residents from the time when the apartments enter the market about the mobility concept, offers and services, and how to use them [13]. In the study area, the implementation of and information about mobility options started only several months after residents had moved. Mobility management could help in such cases to strategically address the topic by timely involving several stakeholders.

It should be noted that due to the low number of 45 respondents and the bias as compared to official statistics, survey results must be generalized carefully. Drawing results from simulation studies also always needs to consider the underlying assumptions. Further, simulations can only include such measures that can be operationalized in the underlying travel demand model and for which there is sufficient data. Thus, while the approach to use a survey and a simulation allows to really test the effects of highly demanded measures on transport in the overall region, it is limited by the scope of the model. Nonetheless, the survey yielded results that were valuable per se even though they could not be tested in the model. Future work should apply a panel approach, investigate the changes in attitudes when implementing new mobility-related measures and track and simulate the use of such measures over a longer period of time. Further, qualitative interviews with residents could provide additional insight on factors corresponding to the use or non-use of services.

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Author contributions
All authors contributed to the study conception and design. Data collection and statistical analysis for the empirical study was performed by Benjamin Heldt and Rebekka Oostendorp. The simulation studies and their analysis was carried out by María López Díaz and Matthias Heinrichs. Results of both parts were synthesized by Benjamin Heldt. All authors contributed to the first draft of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The data of the study will be made available upon reasonable request.

Declarations

Ethics approval and consent to participate
The initial version of this paper was rejected due to a first draft that was submitted to TRA and uploaded to the DLR repository at https://elib.dlr.de/186840/. The submission was withdrawn from TRA procedia and removed from the repository.

Competing interests
The authors have no conflicts of interest to declare.

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