Proceedings

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21. Internationales Stuttgarter Symposium

Automobil- und Motorentechnik

Band 1

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Proceedings

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Mobility

MobiLab - The Mobility Living Lab at the University of Stuttgart

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Abstract. MobiLab is following all in all three approaches: the strategy to reach climate neutrality with respect to the mobility of the University of Stuttgart until 2035, the implementation of the car-free campus Stuttgart-Vaihingen and the offer of the Mobility Living Lab Campus Stuttgart-Vaihingen. To reach climate neutrality in mobility until 2035 the University of Stuttgart acts mainly in the areas of the daily mobility of students and employees (commuting) and of the business trips of the employees. To address the students and the employees since the beginning of 2021 the position of a Mobility Manager at the University of Stuttgart is established. The basic idea of the car-free campus Stuttgart-Vaihingen is to shift all parking lots, which are currently scattered on the whole campus to the edge of the campus, finally in one huge car park covering a motorway. Then these peripheral parking facilities, as well as the already existing station of the regional train system (S-Bahn), will be connected with the campus. This will be done with novel means of transport like automated shuttle buses or a rental system with autonomous e-scooters. In this context, forward-looking electrical propulsion concepts in combination with autonomous driving as well as intelligent systems to store and distribute electrical energy are important research areas. Putting all this together, MobiLab finally forms a multifaceted Mobility Living Lab with the three main research topics “research vehicle”, “research street” and “research multi-storey car park”.

Keywords: Mobility · Car-free campus · Mobility living lab

1 Introduction

MobiLab - under this headline the University of Stuttgart first developed a vision of a nearly car-free university campus Stuttgart-Vaihingen. But MobiLab is more than a vision. In this year the first measures take place to implement MobiLab, going along with several research activities. That´s why the initial concept of MobiLab was both: A visionary mobility concept for the campus Stuttgart-Vaihingen and a living lab for research, development and testing in the area of new mobility related technologies.

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MobiLab in its first phase was the result of an idea competition on an emission-free campus held by the Ministry of Science, Research and Art of the State of Baden-Württemberg. In this idea competition the University of Stuttgart got awarded in the category “University in an Urban Context”.

What forms finally this innovative mobility and research concept? The basic idea of MobiLab is to shift all parking lots, which are currently scattered on the whole campus to the edge of the campus, finally in one huge car park covering a motorway. Then these peripheral parking facilities, as well as the already existing station of the regional train system (S-Bahn), will be connected with the campus. This will be done with novel means of transport like automated shuttle buses or autonomous e-scooters. In this context, forward-looking electrical propulsion concepts in combination with autonomous driving as well as intelligent systems to store and distribute electrical energy are important research areas. Putting all this together, MobiLab forms a multifaceted living lab with the three main research topics “research vehicle”, “research street” and “research multi-storey car park”.

In this moment MobiLab is in its second phase, financed for additional two years by the Ministry of Science, Research and Art of the State of Baden-Württemberg to act as a lighthouse for the transformation to car-free university campuses.

As part of these lighthouse activities Mobilab widened its perspective and is now covering the whole University of Stuttgart. The overall approach for the University is led by the objective to avoid the release of mobility-based CO_2-emissions of the University of Stuttgart (daily mobility of students and employees (commuting), study trips, business trips) until 2035 completely.

With this MobiLab is now following all in all three approaches:

- The strategy to reach climate neutrality with respect to the mobility of the University of Stuttgart until 2035.
- The implementation of the car-free campus Stuttgart-Vaihingen.
- The Offer of the Mobility Living Lab Campus Stuttgart-Vaihingen.

2 Climate Neutrality 2035

2.1 Concept

The objective to reduce the mobility-related release of CO2 as much as possible and to reach climate neutrality until 2035 is part of the sustainability strategy of the University of Stuttgart and is implemented in the strategic development plan of the University.

Figure 1 shows the approach intended to be followed with respect to mobility (daily mobility of students and employees (commuting), business trips).

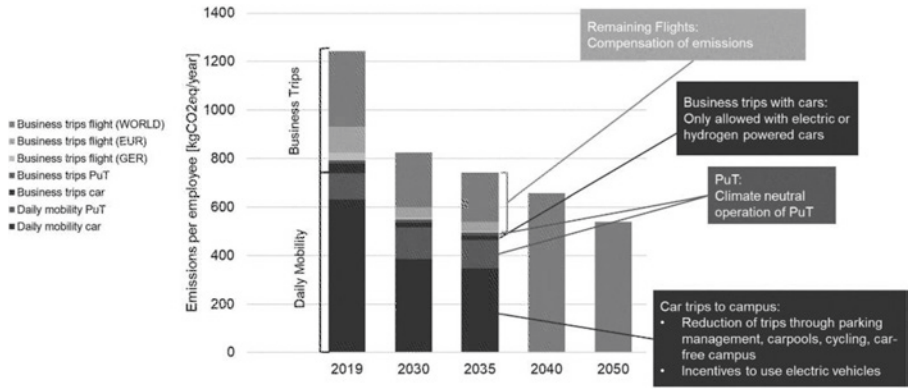

Fig. 1. Climate target 2035 mobility

To reach the settings for the different means of transport the University of Stuttgart intends to implement the following measures and incentives:

- Daily mobility of students and employees (commuting)
  - Reduction of car trips, e.g. with parking management, support of carpools, support of cycling, car-free campus Stuttgart-Vaihingen.
  - Incentives to use electric vehicles, e.g. by offering loading stations, preferential parking spaces for electric vehicles.
- Business trips
  - Business trips with cars only allowed with electric or hydrogen powered cars.
  - No flights anymore in Germany, strict rules for flights in Europe, reduction in the overall number of flights.
  - Additional compensation of the remaining release of CO_2 due to flights.

2.2 The Mobility Manager at the University of Stuttgart

As a first step to change the mobility related to the University of Stuttgart with the beginning of 2021 the position of a Mobility Manager at the University of Stuttgart was established, financed in a first step by MobiLab. The main task of the Mobility Manager is to address the students and the employees of the University of Stuttgart and to accompany them on the way to reduce the release of CO_2 and to find sustainable ways of mobility. This has to be done in an open and communicative approach. Additionally, the Mobility Manager supports MobiLab.

The first activity of the Mobility Manager was to launch a survey among the students and employees to understand their needs for mobility, their mobility behavior and how they rate several measures to shift their mobility to a more sustainable manner.

In 2022 the University of Stuttgart will offer its students and employees an app-based service to form carpools. This will be done in close co-operation with other big employers in Stuttgart, aiming also to form comprehensive carpools.

3 The Car-Free Campus Stuttgart-Vaihingen

3.1 The University Campus Stuttgart-Vaihingen

The campus Stuttgart-Vaihingen of the University of Stuttgart is located in the South-West of Stuttgart, the capital of the state of Baden-Württemberg (see Fig. 2). On three sides it is surrounded by green, but in the East, it adjoins several smaller residential areas. Therefore, it is not possible to enlarge the campus beyond its present boarders even if there is a high pressure to grow. The Campus Stuttgart-Vaihingen is one of the two main sites of the University of Stuttgart.

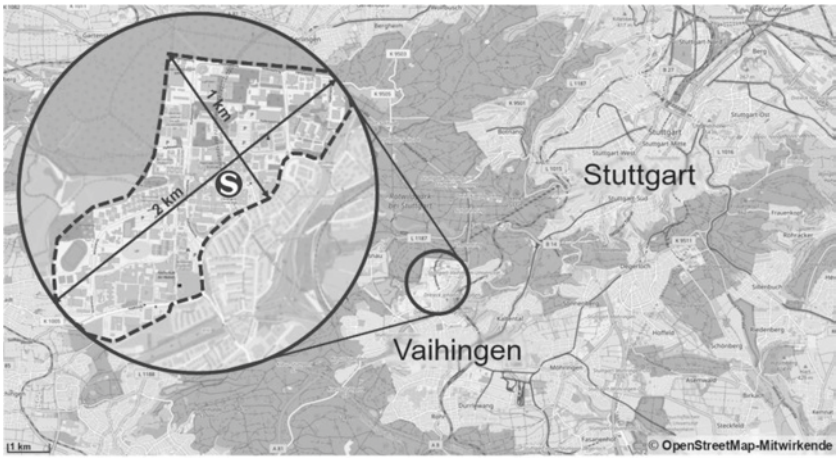

Fig. 2. Location of the campus Stuttgart-Vaihingen

Besides the University of Stuttgart, the HdM (Hochschule der Medien), several Fraunhofer-institutes, the site Stuttgart of the German Aerospace Center (DLR) and numerous other institutions are located on the campus. Additional there is a huge number of student dormitories in combination with several amenities of student´s life. In total there are around 23.000 students studying and nearly 7.000 employees working on the campus.

In public transport the regional train (S-Bahn) station “Universität” is located centrally offering short travel times to both the main station and the airport of Stuttgart. In road traffic the campus is directly linked to both the regional motorway network and to downtown Stuttgart. On the campus nearly 4.000 parking spaces are available.

3.2 The Mobility of Students and Employees

To understand the daily travel behavior from home to the campus and back home as well on the campus of both the students and the employees at the beginning of

the summer term 2019 (April 2019) an online survey was conducted including all students and employees on the campus.

The students travel in average on 3.7 days per week to the campus. The average trip length from their place of residence to the campus is 17 km, resulting in an average travel time of 43 min.

The employees are working in average on 4.3 days per week on the campus. The average trip length from their place of residence to the campus is around 19 km, resulting in an average travel time of 40 min.

The campus is good accessible by public and private transport. The good accessibility in public transport is reflected in the mode choice of the students and the employees (s. Fig. 3). The students use mainly public transport which carries 80% of their transport performance. The employees use public and private transport to the same extent. But in comparison with the residents of Stuttgart or the State of Baden-Württemberg the car usage is clearly lower.

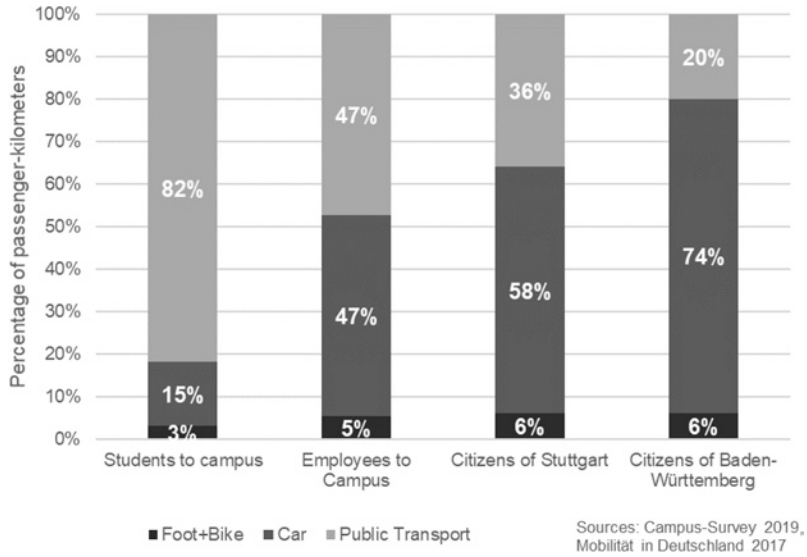

Fig. 3. Modal split of students and employees

3.3 Concept

Overview

The vision of MobiLab is to transfer the campus Stuttgart-Vaihingen to a more or less car free campus. All parking will be concentrated in a central multi-storey car park on top of the B14 motorway at the Southern edge of the campus. This multi-storey car park as well as the already existing regional train station "Universität" will be connected to the campus by autonomous shuttles. An e-scooter rental system on the campus will support the shuttles and improve the mobility on the campus. To connect

the campus to neighboring destinations the bike rental system RegioRadStuttgart was introduced on the campus in 2020.

The area covered by the former parking facilities on the campus will be partly used for new buildings and partly to improve the urban quality of the campus to make it more attractive for employees and students.

There are many components necessary to introduce this mobility concept on the campus Stuttgart-Vaihingen which still must be explored and tested. Here MobiLab is changing to a living lab, the MobiLab Living Lab, where all necessary technologies will be provided. Furthermore, the MobiLab Living Lab will cooperate with many other research activities inside and outside of the University of Stuttgart and offer the campus Stuttgart-Vaihingen as a test bed. Doing this MobiLab is also acting as an incubator for start-ups. A first start-up is already founded based on MobiLab.

To introduce the vision of MobiLab the University of Stuttgart integrates all important players on the campus in the development and implementation of MobiLab: the various universities, research institutes and service providers as well as the students, the employees and visitors. The emission- and car-free campus can only get reality by an interdisciplinary cooperation of different faculties, like transport planning, automotive engineering, electrical engineering, renewable energies, urban planning or social sciences, and an active integration in teaching.

Parking

Figure 4 shows the 3-stage approach of MobiLab related to parking.

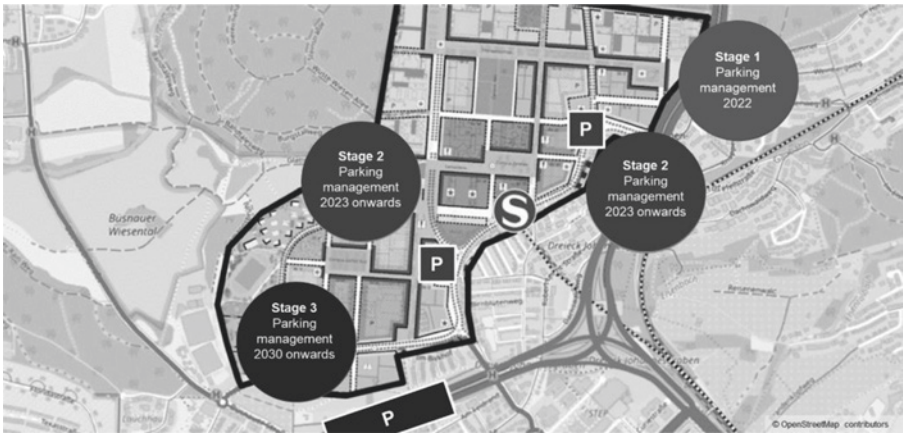

Fig. 4. 3-stage approach parking

In a first stage, most likely in spring 2022, the parking management will be introduced on the campus. Parking management means that students, employees and visitors will have to pay a parking fee, either as a monthly flat rate or as a daily parking fee. The monthly parking fee for the students will be cheaper than the fee for the employees. Following the idea of MobiLab not all the scattered numerous car parks will be administered but the whole campus will be seen as one big car park. Therefore, at the three road entrances to the campus barriers will be installed

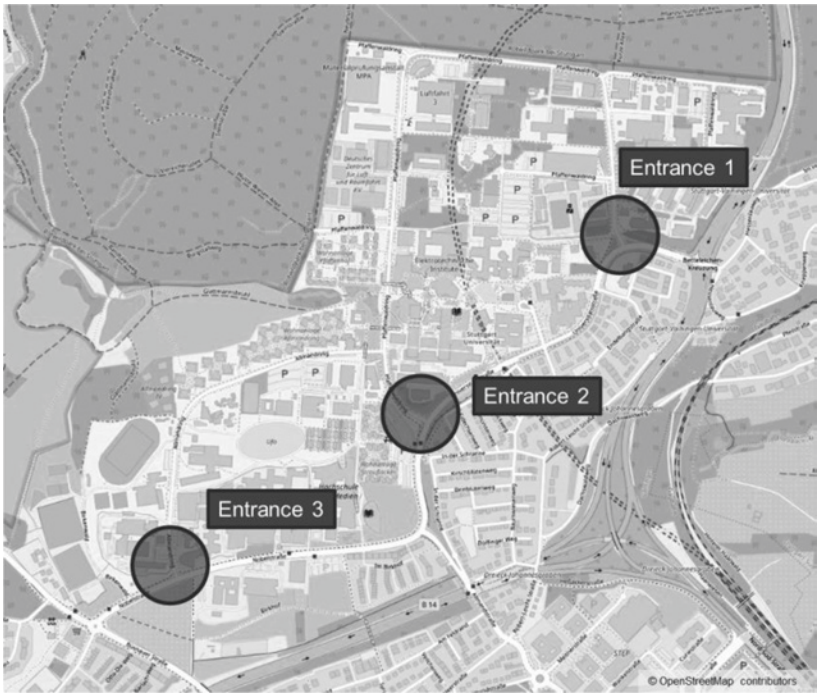

Fig. 5. The three entrances to the campus Stuttgart-Vaihingen

(s. Fig. 5). Behind the barriers all public streets will be closed and dedicated to private streets.

This is already a first important step to the car-free campus. All external car traffic, not related to the campus, will be excluded from the campus.

As table 1 shows, after the implementation of stage 1 of the parking management a parking demand of around 2.900 parking lots remains. Therefore, in stage 2 (not earlier than 2023) two multi-storey car parks will be built as an interim solution until the central parking on top of the B14 motorway will be built which is expected not earlier than 2030.

Table 1. Parking demand (no. of parking lots)

Parking lot requirements	Today	Parking management	Central parking
Employees	2050	1650	1400
Students	1750	1250	1050
All	3800	2900	2550
Parking management: Central	With parking fees of 2€/day Additional 7 minutes of walking and parking fees		

All multi-storey car parks will be designed as “research car parks”:

- Mobility hub in the ground floor (stop of Campus Shuttle, RegioRadStuttgart docking station, bicycle parking, bicycle maintenance area, area for e-scooter rental).
- Charging for electric cars (plug-in, inductive charging).
- Solar panels on the roof, interim storage of electric energy and demand management.
- The two interim multi-storey car parks will be designed in such a way that they can be easily dismantled.

Cycling
In cooperation with the City of Stuttgart, the regional bike rental system. RegioRadStuttgart was expanded to the campus including nine docking stations and offering 72 bicycles and pedelecs. This will increase the accessibility of the campus by bike. The implementation of RegioRadStuttgart on the campus Stuttgart-Vaihingen is the result of a strong initiative of the student´s association stuvus.

In general, the infrastructure for cycling on the campus Stuttgart-Vaihingen has to be improved. First of all, there is a lack of clearly indicated cycle paths. MobiLab will help via the implementation of the parking management scheme, where all public streets will be closed and dedicated to private streets. The second issue to be addressed is parking for bicycles. Here MobiLab intends to build demonstrators for different types of bicycle parking facilities, including at the high end an automatic bicycling parking tower with a capacity of around 120 bicycles.

But there is a need for actions not only on the campus but also in the access to the campus. The campus Stuttgart-Vaihingen has to be integrated in the local and regional cycling networks, especially to the planned cycle highway network, and at least one completely paved cycling connection from downtown Stuttgart to the campus is necessary.

E-Scooter System Campus Vaihingen
Researchers at the University of Stuttgart are currently developing a self-driving autonomous e-scooter (s. Fig. 6). These e-scooters use an advanced control system to drive to the next port of call without the need for a driver. A distribution algorithm optimizes the availability of the e-scooters on the campus. In detail the autonomous e-scooters fulfill the following functions:

- Balancing.
- Autonomous driving without passenger.
- Active navigation.
- Optimal distribution of the fleet.
- Autonomous driving to charging stations.
- Automatic parking with automatic charging.

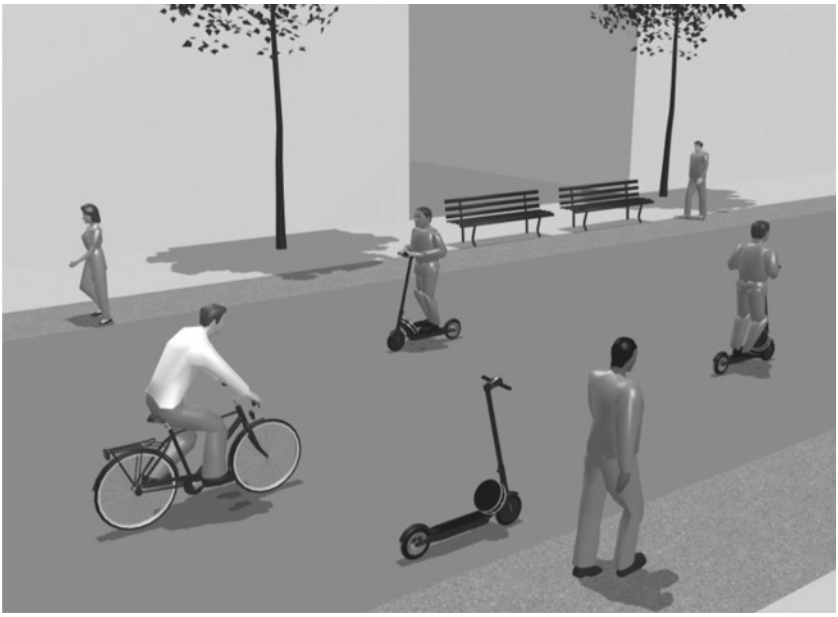

Fig. 6. Simulation of autonomous e-scooters (with and without passengers)

As soon as they are available the autonomous e-scooters will be integrated in the e-scooter rental system offered on the campus. An autonomous e-scooter will replace ten conventional e-scooters in such an e-scooter rental system.

For parking and charging of the autonomous e-scooters a bicycle parking tower (s. chapter Cycling) will be adapted to the specific needs of the autonomous e-scooters.

Campus Shuttle

Intelligent autonomous shuttles connect the central parking facility and the regional train station with the campus. This scenario, named Campus Shuttle, will be real on the campus Stuttgart-Vaihingen in future.

Campus Shuttle integrates different sizes of autonomous (mini) buses, which may have a capacity of six, twelve or 40 seats. Actually, the University of Stuttgart offers the campus Stuttgart-Vaihingen as a test bed for field tests with autonomous shuttles and intelligent shuttle services.

In a first step a traditional line operation will be implemented with a fixed time table and several stops along a circle around the campus (s. Fig. 7). In a second step an on-demand service will be tested. To call the shuttle via smartphone a specific app will be implemented.

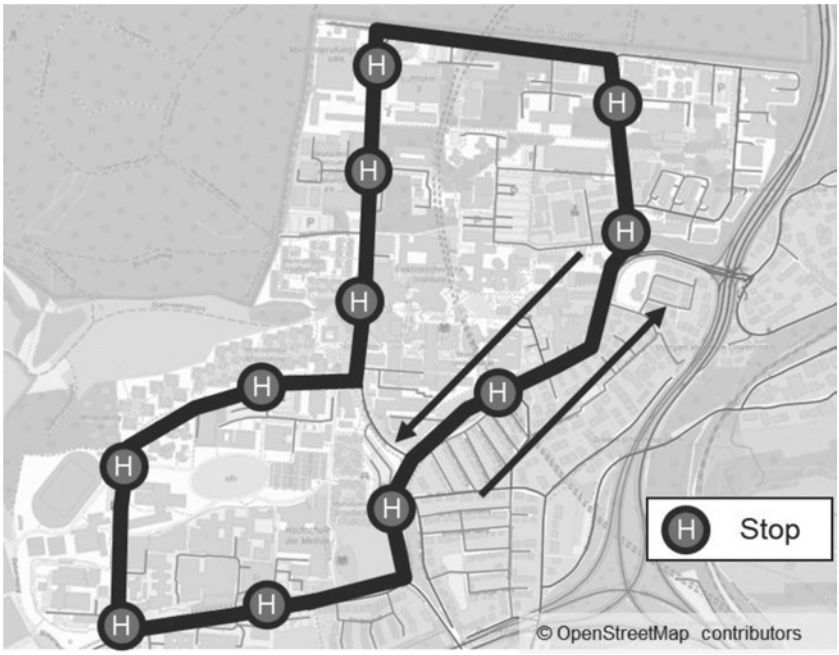

Fig. 7. Alignment campus shuttle

Additionally, the shuttle will be used to test several approaches in the area of energy storage and electric actuation. Some parts of the so called “research street” will be prepared for inductive charging while driving.

4 The Mobility Living Lab Campus Stuttgart-Vaihingen

The University of Stuttgart shapes with MobiLab the vision of an emission-free campus Stuttgart-Vaihingen. The campus will be a research campus - the Mobility Living Lab -, where climate-neutral, electric and intelligent mobility will be tested (s. Fig. 8). This Mobility Living Lab will be formed by the components “research vehicle”, “research street” and “research multi-storey car park”. The Mobility Living Lab offers students, lecturers and researchers a versatile test bed in the areas of sustainable mobility based on renewable energy, of autonomous driving and of artificial intelligence. It forms a living lab for diverse institutes from transport planning, automotive engineering, computer science, electrical and information engineering and social sciences.

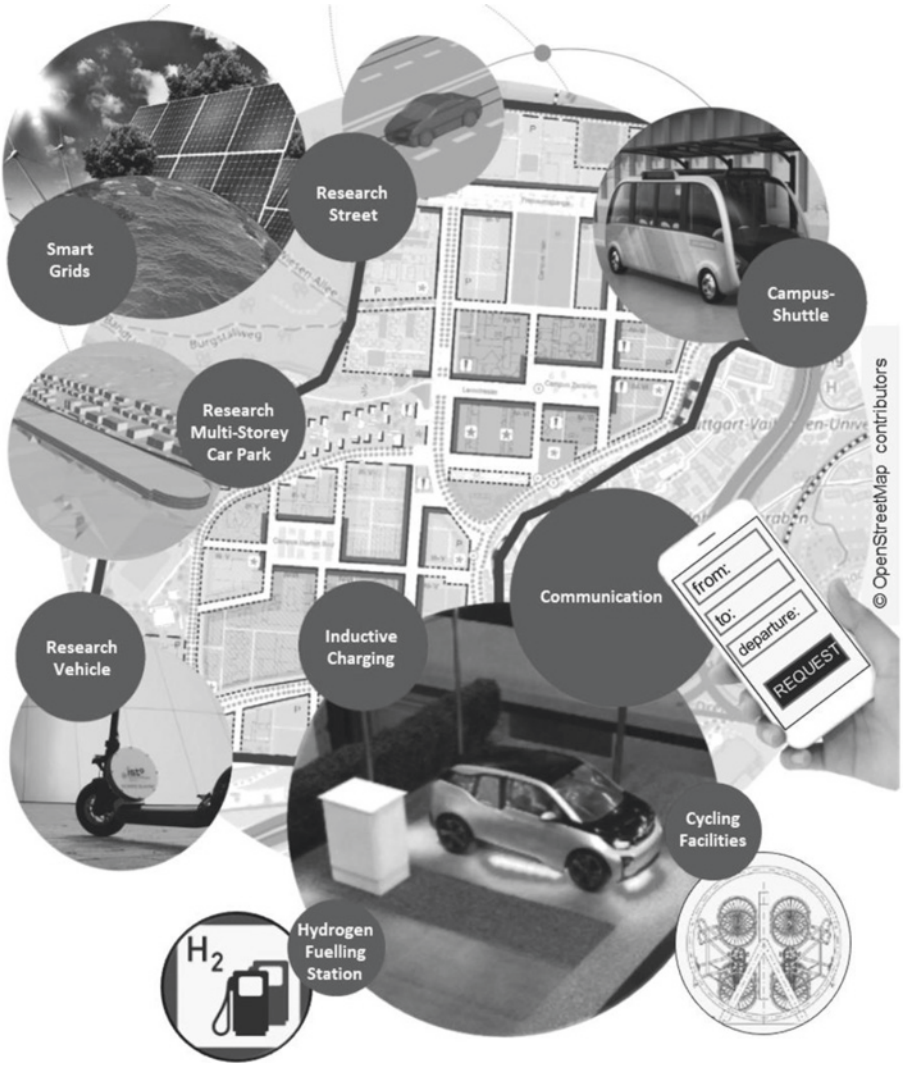

Fig. 8. The mobility living lab campus Stuttgart-Vaihingen

The "research vehicles" will be the autonomous e-scooter and the autonomous shuttle.

Due to the innovative concept to introduce parking management as an area-wide approach "behind the barriers" all roads on the campus will be part of the "research street" and will be open for several research activities. These activities include the implementation of equipment for inductive charging, but also field tests of the co-existence of traditional bicycles, autonomous e-scooters, autonomous shuttles and traditional vehicles on the same street.

The “research multi-storey carparks” will be equipped with several specific features as already described in chapter “parking”.

Again, all research activities are not limited to the basic ideas of MobiLab. The Mobility Living Lab MobiLab offers the campus Stuttgart-Vaihingen for all interested in mobility-related research.

5 Outlook

The implementation of MobiLab already started. This is done in a strong cooperation with the mobility concept which in parallel is under elaboration in this moment. The mobility concept deals with the present mobility and transport needs on the campus Stuttgart-Vaihingen to be solved, while MobiLab shapes the future of the campus. The mobility concept integrates the activities of MobiLab and prepares their implementation.

The parking management on the campus Stuttgart-Vaihingen will start in spring 2022. It is strongly influenced by MobiLab and forms an important first step for the implementation of MobiLab.

RegioRadStuttgart is already implemented on the campus Stuttgart-Vaihingen.

The first prototype of the autonomous e-scooter is already under operation and able to stabilize itself while driving.

In 2022 the operating test of the campus shuttle will start.

MobiLab itself is an inter-disciplinary research network, including the administration of the University of Stuttgart. Now MobiLab has to be integrated in the University of Stuttgart in a broad approach aiming to connect all mobility and transport related research activities within the University of Stuttgart.

In parallel MobiLab is also integrated in several European networks also offering them the campus Stuttgart-Vaihingen as a Mobility Living Lab and a test bed for a wide variety of mobility related test applications.

But also, in teaching MobiLab offers many possibilities to get integrated in lectures, exercises or case studies. First master theses in the framework of MobiLab are already finished.

MobiLab is integrated in the sustainability-related activities of the University of Stuttgart giving advice to the administration of the University but also supporting students and researchers with their ideas.

Additional MobiLab widens its perspective and will take care for the whole University of Stuttgart. In this moment a monitoring instrument for both daily trips to the university and back home and for business trips of the employees is available. In a first step regular reports will be published to the students and employees to raise awareness on the respective mobility behavior. In a second step the University of Stuttgart will publish verifiable objectives to reduce the ecological footprint of the university and will take measures to fulfill these objectives.

MobiLab gives already advice for new buildings. It recommends to provide parking facilities for bicycles (plus showers for the cyclists!) and areas for the

e-scooter rental system or to make as much as possible use of the roof or the façade to produce renewable energy which can be used for charging of electric vehicles.

All these activities opened the awareness of the University of Stuttgart to limit such considerations not only on mobility but also to work on the sustainability of the stock of existing and planned buildings.

Self-Propelled Trailers – An Approach to Type Approval

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Abstract. Today's technological change into alternative power trains is having massive impact beyond the vehicle itself. Tests are showing that air streamed electric vehicles are reduced by half in reach towing a trailer, especially a caravan. In order to compensate for the significant loss of traveling distance with a single battery charge EHG, ZF and FKFS are designing a battery electric propelled caravan. In addition to the technical aspects that have already been presented, the approval of powered trailers poses various regulatory challenges. A vehicle category or definition for powered trailers does not yet exist and must therefore be newly created in coordinated association work and in close cooperation with the relevant approval authorities. The additional weight that is created by the drive components represents further requirements in terms of driving license and trailer load. The limit of 3.5 t should be emphasized here. Compensation for the additional weight is therefore necessary.

Keywords: Trailer · Propelled trailers · Electric vehicles · EV reach

1 Introduction/Motivation

Electric powered vehicles today are optimized to handle electric power highly efficiently. They feature low loss bearings and aerodynamic design. And they have to carry additional weight at about 10 kg/kWh installed battery capacity. With the resulting in average to 700 kg on top. Thus by often working in an "old" chassis platform and brake set-up taking away towing capacity. Maybe at least this is why we see today trailer hitches only with high power cars often even with reduced towing capacity in the order of the battery weight.

Towing a caravan is a real challenge for EVs. The bulky caravan completely spoils all aerodynamic achievements of the towing car. Published tests with an electric vehicles towing a caravan are showing a cut down of the reach nearly by halve [1]. To compensate for this loss of reach, the battery capacity simply has to be doubled. But which car manufacturer has doubled the fuel tank, just to be able to tow? Our proposed solution is to put the additional required motive power and energy where

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