HUPMOBILE

ITS – Intelligent Transport Systems

HUPMOBILE – Holistic Urban and Peri-urban Mobility
Report, 2021

Imprint

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Project note

The EU co-funded project **HUPMOBILE – Holistic Urban and Peri-urban Mobility** (2019–2021) brings together municipalities, universities and other expert organisations in their efforts to develop a holistic approach to the planning, implementation, optimisation and management of integrated, sustainable mobility solutions in the Baltic Sea port cities.

The carried out activities enable major urban mobility stakeholders such as city authorities, as well as infrastructure providers and transport providers to assess and integrate innovative mobility options into their mobility management plans and policies. The developed HUPMOBILE framework allows the planning and implementation of well-functioning interfaces and links in urban- and peri-urban transport considering the different transportation flows in the local context.

Within HUPMOBILE, partner cities plan, test and implement innovative sustainable urban mobility for both people and goods (i.e. freight, cargo logistics and delivery), which are easily adoptable for follower cities. These include greener urban logistics and combinations of goods- and passenger traffic, intelligent traffic systems-based services, tools for stakeholder participation, and new tools for transportation mobility management and Mobility-as-a-Service (MaaS).

Content

Introduction

The Borough of Altona of the Free and Hanseatic City of Hamburg is a project partner in the European Interreg project "HUPMOBILE". Together with the Baltic partner cities Tallinn, Turku, and Riga, sustainable approaches to the control, optimization, and management of traffic and transportation are to be developed under the leadership of Aalto University Helsinki. To this end, the Hamburg-Altona district office is working ~~.~~ The study on the potential analysis of intelligent transport systems (ITS), which forms the basis for the digitalization of traffic and mobility, is presented below. Intelligent transport systems are an indispensable component on the way to a smart city. Only if digitization is used productively and existing modal boundaries are dismantled can borderless mobility prevail as a genuine alternative to individual motorized transport.

As a model city, Hamburg wants to demonstrate the opportunities of digitization for traffic and also rely on intelligent transport systems. For this reason, a comprehensive ITS strategy, which serves as the basis for the study, was already developed in April 2016. Thus, numerous pilot projects have already been carried out or are currently being tested in connection with ITS. In addition, the ITS strategy pursues the aforementioned shift to environmental connectivity. With hvv switch[1] and the included mobility app and IT platform, the foundations are already in place and need to be further developed.

In addition to a theoretical and scientific approach to the term ITS, which is often defined differently from mobility as a Service (MaaS), this report aims to analyze potential. The aim is to define three different areas of investigation with varying conditions of traffic and needs and then to identify possible ITS-based measures.

The selection of the study areas is based on different spatial and traffic characteristics that can be found in large cities and port cities. Thus, the transferability to the HUPMOBILE partner cities is given. Since ITS should contribute to reducing motorized individual traffic, this study supports the overall goals of HUPMOBILE.

[1] Hvv-switch is the platform in Hamburg that makes public transport and other forms of mobility available in an app. More information is available at www.hvv-switch.de

1. ITS – Intelligent Transport Systems

European cities are facing numerous challenges that can be related to transportation. Examples include the economic costs resulting from traffic congestion, high CO_2 emissions, 23 percent of which are caused by the transport sector in urban areas, and the numerous personal injuries suffered by road users. According to calculations by the European Commission, there is enormous potential in the transport sector to reduce greenhouse gases by up to 60 percent by 2060[2]. Sustainably managing urban transport means finding a balance between sustainability, safety, efficiency, and quality of life. The increasing demand for transport combined with the individual requirements of different road users, consisting of pedestrians, cyclists, public transportation, and motorized vehicles, complicate this process considerably. To manage these challenges and conflicts, ITS systems can play a decisive role as an instrument.[3]

1.1. ITS - Definition

"Intelligent Transport Systems "(ITS for short) stand for the digitalization of the mobility and logistics sector. In addition to collecting and presenting data on vehicles and the goods they transport, ITS also includes the transmission, processing, and use of traffic-related data in real-time. ITS is also a component of car-to-x communication. Examples include construction site management or communication between traffic signals and motor vehicles. The goal is more efficient, safer, and more sustainable handling of all traffic with the help of information and communication technologies (ICT)[4]. ITS is, therefore, a subarea of the ICT spectrum, with ITS representing the application of ICT in traffic and transportation. The innovative services should apply to all modes of transport and traffic management systems. The various users are better informed, and traffic flows are coordinated as intelligently as possible. This form of definition is already reflected in that of the World Bank from 2004: "The application of IT to surface transportation is called "Intelligent Transport Systems" (ITS). ITS provides the ability to gather, organize, analyze, use, and share information about transportation systems."[5]

[2] The target is aligned with the current climate targets in Germany.
[3] CIVITAS (2015): 6
[4] CIVITAS (2015): 9
[5] World Bank (2004): 3

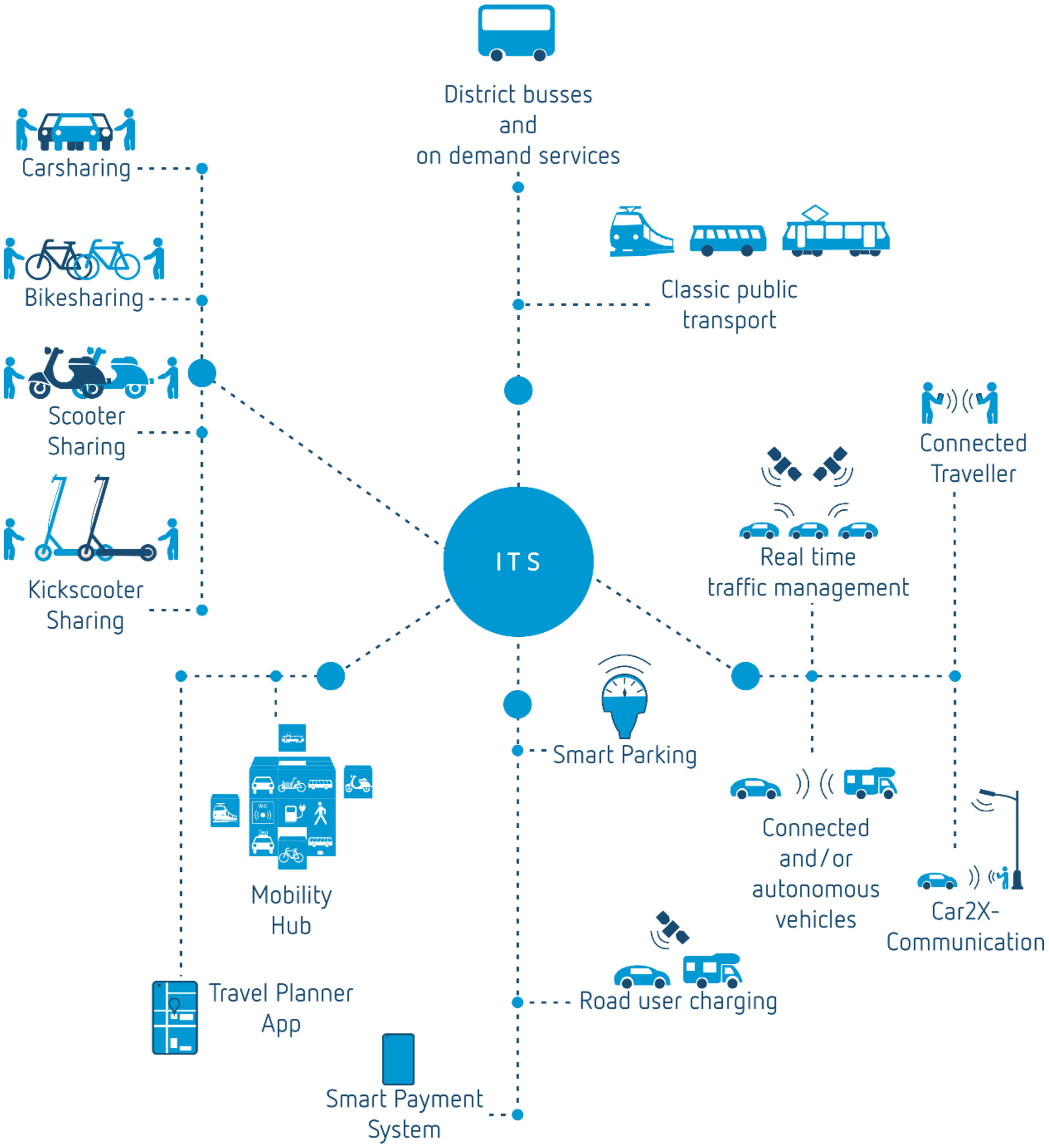

Figure 1: ITS-spectrum (source: own illustration, Planersocietät)

A more detailed definition can be found for the first time in the European ITS Directive from 2010: " 'Intelligent Transport Systems' or 'ITS' means systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles, and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport"[6].

In the course of advancing digitization, far more opportunities have been created than were foreseeable in 2004. The digital transformation offers enormous potential and opportunities for urban transportation. Intelligent transportation systems can be divided into 16 different technology-based systems as examples (s. Figure 1). These, in turn, can be divided into two main categories under which all forms can be subsumed:

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[6] Directive 2010/40/EU of the European Parliament and of the Council of 07.07.2010

- Intelligent infrastructure
- Intelligent vehicles

Figure 1 illustrates the broad (but not exhaustive) spectrum in which ITS can be applied in mobility. In addition to this general classification into Intelligent Infrastructure and Intelligent Vehicles, a much more differentiated categorization seems possible. Figure 2 organizes ITS measures into six different categories, with additional essential subcategories for cities.

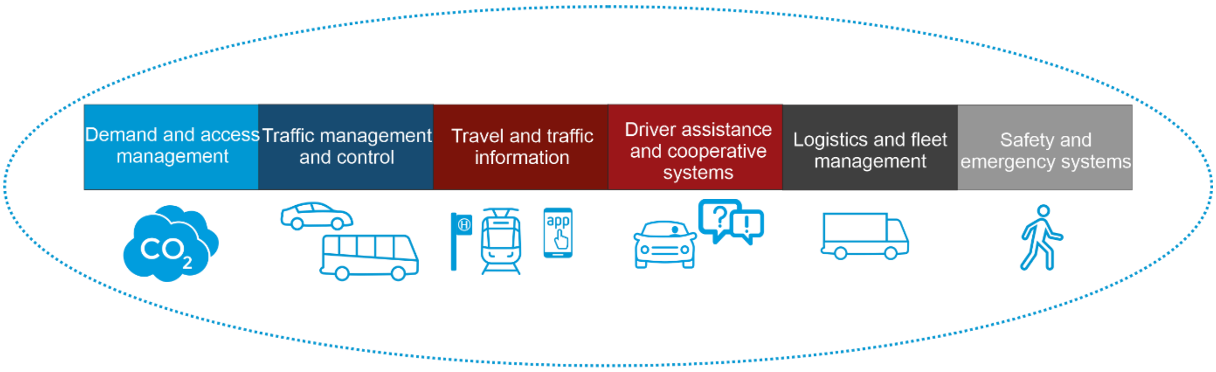

Figure 2: ITS-categorization (source: own illustration, Planersocietät)

The most relevant areas of an ITS strategy for municipalities are demand and access management, traffic management and control, and travel and traffic information[7]. In this context, ITS systems are an integral part of numerous innovative concepts, such as smart cities, mobility as a service (MaaS), or connected and automated vehicles (autonomous driving). Roof demand and access management aim at improving traffic flow, which plays a crucial role, especially in city centers in the context of air pollution. This is achieved by variable switching of traffic signals, which, depending on capacity, control traffic flow in a targeted manner and, if necessary, regulate speeds in a time-variable way. Thus, on the one hand, ITS can improve network management or increase productivity in the infrastructure and, on the other hand, avoid the physical expansion of the infrastructure. This is estimated to save more than 20 percent of the costs incurred.[8]

Consequently, ITS applications are establishing themselves in the classic traffic management structures. Traffic management is the instrument for achieving the (political) goals of a city. Other examples of traffic management measures include optimizing existing resources on traffic routes, parking space utilization, and avoiding empty trips. Thus, traffic management aims to solve traffic problems by controlling the traffic of the different modes of transport or by shifting traffic to individual modes

[7] Eltis (2019): 6 f.
[8] Eltis (2019): 6

of transportation (e.g., local public transport). ITS systems can also be an advantage for travelers as an essential requirement. For example, their components, such as MaaS, serve to make the booking process more convenient by simplifying the payment process in a customer-oriented manner. In addition, data on travel and traffic information is collected, bundled, and processed in real-time. In general, there is a definitional deficit in the literature that separates ITS from MaaS, two diffuse concepts. In this report, ITS is the basis for collecting and processing data and linking it to other information. If the data is used by end-users to plan their trip, it is MaaS. Thus, ITS provides the basis for travelers' decision-making regarding their transportation mode or route, thus enabling traffic problems to be reduced. In summary, numerous traffic management measures use ICT and can therefore be described as ITS applications.

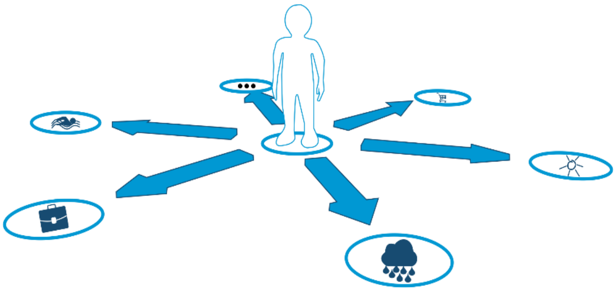

Figure 3: ITS as the basis for user-centric MaaS (source: own illustration, Planersocietät)

The category of driver assistance and cooperative systems covers the networking of vehicles with each other (vehicle-to-vehicle, V2V), the networking of vehicles with the infrastructure (vehicle-to-infrastructure, V2I), the networking of vehicles and IT centers (vehicle-to-IT-backend, V2B), and in the future also between cars and cyclists and pedestrians. This technological development offers completely new possibilities that go far beyond the simple sensory recording of a single-vehicle.

In summary, the embedding of ITS systems in the different areas of a city shows the formative function ITS can take in future development. With the help of ITS applications and the associated measures, numerous traffic problems in a city can be partially solved or at least reduced. Thus, an Intelligent Transportation System with multiple potentials is an integral part of a modern mobility strategy.

Excursus: Smart Cities

Smart city is a collective term for technological concepts that pursue the goal of making cities more sustainable and efficient. The expansion of information and communication technologies (ICT) in particular is seen as a driver of smart city evolution and is having an ever-increasing influence on urban infrastructures in everyday life. The relevant specialist literature shows that the term smart city is often difficult to grasp and is not well defined. The reason for this is that smart can be associated with intelligent, clever, efficient or even integrative. The city of Vienna is considered to be a pioneer of smart cities in Europe, and the Vienna municipal utilities see the following advantages in technological urban development: Reduction of resources, increase of quality of life, higher competitiveness as well as integration and networking of: Energy, mobility, urban planning and governance structures.

The concept of the smart city is in parts difficult to distinguish from other terms of different city categories. One example is the sustainable city (Green City, Eco City), which promotes ecological and sustainable urban development and transfers the guiding principles, goals and measures to the Smart City. Other synonyms that belong to the Smart City family of concepts are the Digital City (internet-based city) and the Intelligent City (digital city & innovation).

A smart city can generally be divided into two different approaches. The first approach envisions purely technological development as the authoritative component in urban development. Wireless telecommunication networks and digitally controlled traffic networks are used to monitor, manage and regulate city flows in real time. In addition, data generated by the users themselves is processed. Analyzing this data in turn offers improved efficiency in urban city development. The second approach does not pursue a purely technological development, but a general development of a knowledge-based economy. ICT is used here as a central instrument for realizing innovation. The decisive factor here is the link to human and social capital.

The biggest proponents of smart city development are the large technology companies, such as IBM, Cisco, Intel or Siemens AG, which are opening up a new market segment. Their influence on urban development is already evident in numerous examples. One example is in Rio de Janeiro, where IBM is building an Intelligent Operations Center, which will monitor all urban structures, at a cost of nearly $15 million.

The European smart city development is in contrast to the so-called greenfield projects New Songdo from Korea or Masdar City (ARE), where the cities were newly built and are already fully technologically equipped at the beginning. In Europe, the smart city theme is approached through lighthouse projects and through competition, driven by funding. One well-known example is the EU project mySmart-Life from Hamburg, which is funded under the EU's Horizon2020 framework program for research and innovation. Individual projects are intended to address the four target areas of energy, mobility, communication and innovative citizen participation. Part of the mobility target area is primarily e-mobility and sharing services.

1.2. Opportunities and Challenges

The establishment of an ITS concept or strategy is associated with numerous chances/opportunities and challenges. Multiple cities are using ITS services in real projects to recognize many advantages for sustainable urban mobility. However, ITS solutions are tailor-made approaches for the respective city and the respective actors so that advantages or disadvantages are always location-specific.

In general, ITS can increase the efficiency of the transportation sector. Examples of this are prioritizing public transport at traffic signals or real-time information about accessible parking spaces, which reduces parking search traffic. Thanks to the development of mobile technology and the digitalization of public space, access to mobility as a Service has become possible more recently. MaaS can optimize travel and move travelers to more sustainable modes of transportation through a seamless travel experience.

Transferred to the transportation governance capabilities within a municipality, the digitization of transportation can also be established in existing tools. For example, ITS can be a means for cities to introduce measures resulting from transport development plans and mobility concepts. This is done in a more integrated and cost-efficient way. In addition, the development of an ITS infrastructure creates conditions for fully integrated and intelligent mobility.

In addition to the opportunities and benefits of ITS systems, there are also many challenges. Since each city is unique, a customized ITS solution must adapt to the local context and in line with a city's vision and goals. ITS implementation requires broad expertise from different knowledge domains. This requires collaboration across administrative boundaries, as well as city, regional and national boundaries.

Another essential aspect is compliance with the legal framework. On the one hand, an ITS architecture that is as open as possible is necessary so that all providers can access the data. On the other hand, data protection is considered a very high priority in Germany. In data collection and processing, it is elementary to agree on specific open standards.

One major challenge at present is still technical. For example, there is no uniform global standard for data transmission. Currently, two different technologies are competing for vehicle networking. Backend-based communication via the mobile network on the one hand and ad-hoc networking via WLAN derivative on the other. Therefore, it is unclear how these two incompatible technologies are to be countered or how they can be ensured that all vehicles (and objects) can exchange information.

1.3. ITS in Europe

In Europe, there is no legal requirement to equip V2X technology. However, back in 2010, the European Union adopted the" Directive on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport"[9]. In 2014, representatives of the EU Commission, industry, and public authorities agreed on a 140-page final report within the framework of a working group, which addresses both technical details and issues relating to legal implementation, data protection, or international cooperation[10]. The 2010 Regulation was finally extended by the 2019 Deligated Regulation (EU) supplementing Directive 2010/40/EU of the European Parliament and the Council regarding the deployment and operation of cooperative intelligent transport systems. Despite these excellent and essential approaches, however, a uniform standard has still not been agreed upon. Critics, therefore, fear "the danger of parallelism between different, incompatible systems. This would mean that both technologies might have to be installed in the vehicle, which would entail higher acquisition costs. In addition, consumers could incur unnecessary costs due to mobile transmissions instead of WLAN. Car manufacturers could become unnecessarily dependent on chip manufacturers and mobile network providers. The public sector would lose investments that have already been made in open WLAN infrastructures[11]". On the other hand, the "principle of technology neutrality" is cited as a reason against such a definition.[12]

Regardless of the technological issues, there are already several similar activities and initiatives in Europe to promote ITS development. In an extensive evaluation of ITS projects in Europe, 122 best practice projects were identified. The majority of the projects come from Great Britain, France, and Germany. Figure 4 shows to which areas the ITS projects are to be assigned[13]. Individual European projects are described below as examples.

European ITS-Projects:

Smart Ways to Antwerp: The Smart Ways To Antwerp Route Planner is an intermodal route planner that uses real-time mobility data and information on all modes of transport to provide the user with recommendations for a trip. In addition, users can create a personal account where personal preferences can be stored. To promote a modal split focused on the environmental network, an intermodal route planner was developed to provide users with a combined mobility offer (walking, car, train, bike-sharing, and bus). Since Antwerp has a high volume of commuters, the route planner works throughout the BeNeLux region. For example, the parameters used (for example, maximum

[9] Directive 2010/40/EU of the European Parliament and of the Council of 07.07.2010
[10] C-ITS (2016): 10 ff.
[11] Deutsche Bundesregierung (2019): 2 ff.
[12] s.O.
[13] Aifadopoulou et al. (2014): 58 ff.

walking time, maximum walking distance, P+R facilities, restrictions for cars, etc.) to calculate the real-time travel time were defined by the municipality[14].

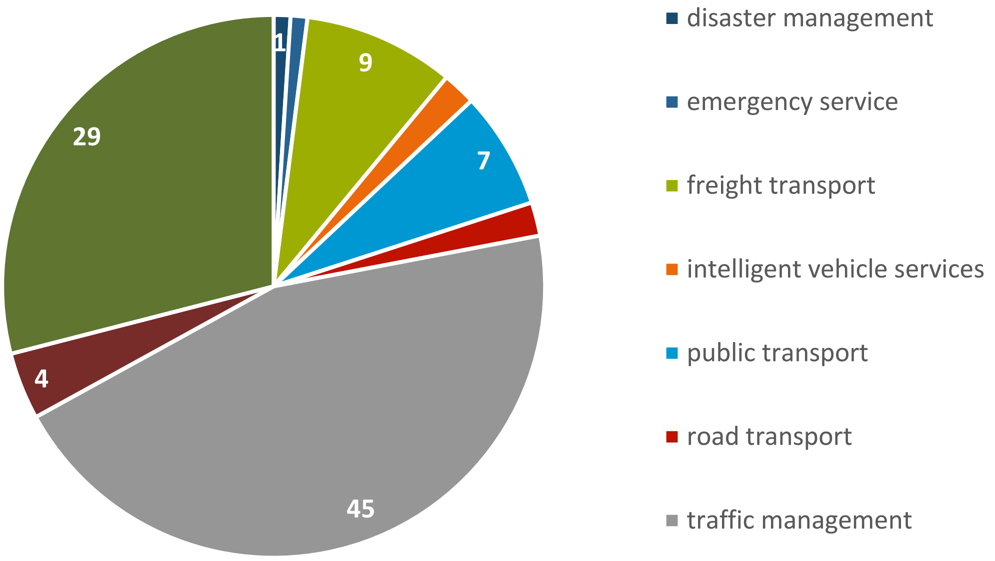

Figure 4: ITS-Projekte Europa (Source: own illustration, Planersocietät, according to Aifadopoulou et al. (2014): 60, data in percent)

Urban Parking in Bordeaux: In Bordeaux, an entire parquet for motorists consisting of various mobility services is tested. Drivers enter their location and their desired destination. The data is then compared with data on available parking spaces, for example. Furthermore, there are suggestions and hints to reach the desired goal with different means of transport at other travel times. Preferably, free parking spaces in peripheral locations are selected to avoid high traffic loads in the city center. To offer an incentive to car drivers, public transport tickets are offered at reduced prices or even free of charge[15].

Truck traffic management in Helmond: With green-light-optimal-speed-advice (GLOSA), the city of Helmond has developed a system that provides an optimal speed recommendation for heavy goods transport so that trucks can identify their approaches to intersections and avoid unnecessary stops. In this way, GLOSA reduces inner-city emissions triggered by heavy-duty vehicles in particular. [16]

[14] Smart ways to Antwertp (2021): https://www.slimnaarantwerpen.be/en/combining/smart-mobility-apps-for-personal-use
[15] European Union 2021
[16] Mehr unter https://www.helmond.nl/error?aspxerrorpath=/BIS/2007/notities

2. ITS in the Free and Hanseatic city of Hamburg

The Free and Hanseatic City of Hamburg is a growing metropolis in Europe. Due to an increasing number of inhabitants, a rising volume of freight traffic, increasing numbers of commuters and tourists, and an ever-increasing range of means of transport, both mobility needs and mobility demand are growing. In the next few years, it will be necessary to minimize the harmful effects of mobility on the one hand and to generate new mobility opportunities on the other. Currently, numerous central traffic routes are overloaded due to the excessive use of private motorized transport. Nevertheless, there are signs of a trend reversal here. The use of individual motorized transport is declining in the inner-city area, and public transport or the bicycle, as well as new mobility offers, are increasingly being used. Nevertheless, mobility-related emissions, parking search traffic, and traffic jams are increasing. To solve these problems and ensure safe, sustainable, and affordable mobility in the Hanseatic city, ITS can make a significant contribution by taking advantage of the opportunities offered by digitalization for transport.

In general, Hanseatic city has long set itself to make mobility as environmentally friendly as possible through targeted offerings. Numerous different players in the city and business and science are working to develop Hamburg into a model city for urban mobility and logistics solutions. The overarching framework for the further development of mobility in Hamburg is the Mobility Program 2013[17]. A significant milestone for the implementation of the ITS strategy, which was adopted by the Senate in April 2016 and updated in 2018, and for achieving the goals set for the fields of action 2030, is the ITS World Congress in 2021, which the Free and Hanseatic City of Hamburg will hosted[18].

The ITS strategy is part of the overall "Digital City" strategy. The further development of a traffic management system with ICT into an intelligent transport system is also part of Hamburg's climate plan. With the digital city, Hamburg has set itself to assume a leading role among European cities in digitization. The ITS strategy is the responsibility of the Chief Digital Officer at the Ministry of Economic Affairs, Transport and Innovation (BWVI), who is responsible for steering, strategic planning, coordination, and monitoring. In general, the strategy serves as a central basis for managing ICT use and, in particular, for structuring innovative new digital technologies and services in transportation. This is done jointly in coordination with associations, companies, and research institutions. Overall, the 2016 ITS strategy defined goals in various fields of action, formulated in a 2018 progress report as interim goals for 2021 and as an overall strategy for 2030. Thus, the progress report provides an outlook on which key projects are to be implemented in the medium and long term.

[17] In 2013, Hamburg presented a mobility programme as a basis for entering into continuous transport development planning. It describes the general transport conditions in Hamburg, the existing starting situation and measures and projects for the coming years. The transport development plan s currently being revised. The resulting measures are to be compared with the ITS potential analysis. The plan is available at www.hamburg.de/contentblob/4119700/data/mobilitaetsprogramm-2013.pdf

[18] https://itsworldcongress.com/

2.1. Initial Situation - ITS in stock

Compared to other major German cities, Hamburg already has an excellent technological basis for implementing ITS systems across the board in the future. Thus, the following established methods will be reprocessed in the overall context of the ITS strategy. The existing offerings can be found in the city as well as at commercial enterprises[19].

Highways

Notable existing ITS applications include the network control systems on the A1, A7, and A21 freeways. Using variable message signs on modern display panels, road users can be informed and, in the case of highly congested stretches of road, diverted in a targeted manner. The data is fed by traffic cameras and additional traffic data - floating car data. The resulting derived traffic image - level-of-service - makes it possible to determine how busy a route is and, if necessary, to select an alternative route before the journey begins. In addition, Hamburg and Schleswig-Holstein have jointly developed the A7 North app. In addition to real-time travel times, this also shows roadworks or dynamic route guidance. In addition, current traffic events are streamed live from 14 locations.

Harbor

For the Port of Hamburg, the smartPort logistic project has created an IT platform that bundles all information, such as the current traffic situation, free parking spaces, or goods data. It enables direct communication between the stakeholders involved. Truck drivers are informed via DIVA (Dynamic Information on Traffic Volume in the Port).

ITS in urban traffic

Numerous ITS systems are already in place in urban traffic as well. These include the approximately 1,700 traffic signals, 90 percent of which are controlled by a traffic computer. However, it should be noted that these systems are based on traffic counts and not on real-time information. Only on isolated sections is the Hamburg Adaptive Network Control (HANS) used, optimizing the traffic flow based on real-time measurements. In addition, a large amount of information is bundled in the traffic control center. If there are corresponding disruptions in the traffic flow, employees can initiate measures at an early stage.

The search for parking spaces in various parts of Hamburg is controlled by ITS-supported systems. For example, free parking spaces in 57 parking garages with almost 30,000 parking spaces are dynamically displayed via display panels, which means that parking search traffic can be specifically avoided. Currently, there are no dynamic displays at P+R facilities.

[19] Amt für Wirtschaft, Verkehr und Innovation (o.J.): 8 ff.

As in many other large cities, public transportation in Hamburg is the backbone of the transportation system that makes intermodality and multimodality possible in the first place. Passengers receive real-time information via the HVV app and the digital passenger information systems at the respective bus stops. The public transport offer is supplemented by integrating car-sharing vehicles and the StadtRAD (public bike sharing system) at the hvv switch points.

2.2. ITS-Strategy: Objectives and fields of action

Due to the potential enabled by ITS, there are numerous opportunities for Hamburg to shape future-proof and sustainable mobility in a metropolitan region. ITS in the transport sector means enabling safe, efficient, and sustainable locomotion. Overall, the ITS system in Hamburg is expected to contribute to the following goals:

- Increase traffic safety
- Reduce traffic-related environmental impacts
- Increase reliability and efficiency
- Support good and safe information collection and distribution
- Promote innovation

To achieve these goals, the City of Hamburg developed an ITS strategy in April 2016 to help embed digital developments into Hamburg's transportation system. However, it should be noted that the expansion of ITS applications must not counteract the attention of transport participants to technological surfaces and road traffic.

Another objective of the influence of ITS is to optimize the flow of traffic within the city so that fewer pollutants are emitted overall and noise emissions can be reduced. The share of the environmental alliance in the modal split is also increased with the increase in attractiveness of intermodal transport offers. However, there is still a conflict of objectives in that the optimized traffic flow may lead to increased use of private cars, which would not achieve the desired effects.

User groups of different means of transport have other demands. However, the expected demand for an efficient infrastructure with reliable real-time travel times is increasing for all of them. The more transparent and easy-to-use individual mobility options are presented, the more often they will be used. Fares, payment processes, and intermodality and multimodality options are bundled by ITS systems and made available in a user-oriented manner (s. ITS-Projekts Hamburg, Kap. 2.3).

High quality of real-time information is crucial for acceptance among users of ITS systems and services. For this purpose, the data must be made available digitally in standard formats to all interested parties. Relevant here are DATEX-II (European standard for the exchange of traffic data) or Open GIS Consortiums. In addition, personal data must be protected against misuse.

In addition, the ITS strategy promotes innovation in the field of urban mobility. The complexity of the topic requires the testing of numerous approaches in various ongoing pilot projects, which must be subjected to a comprehensive monitoring process after completion.

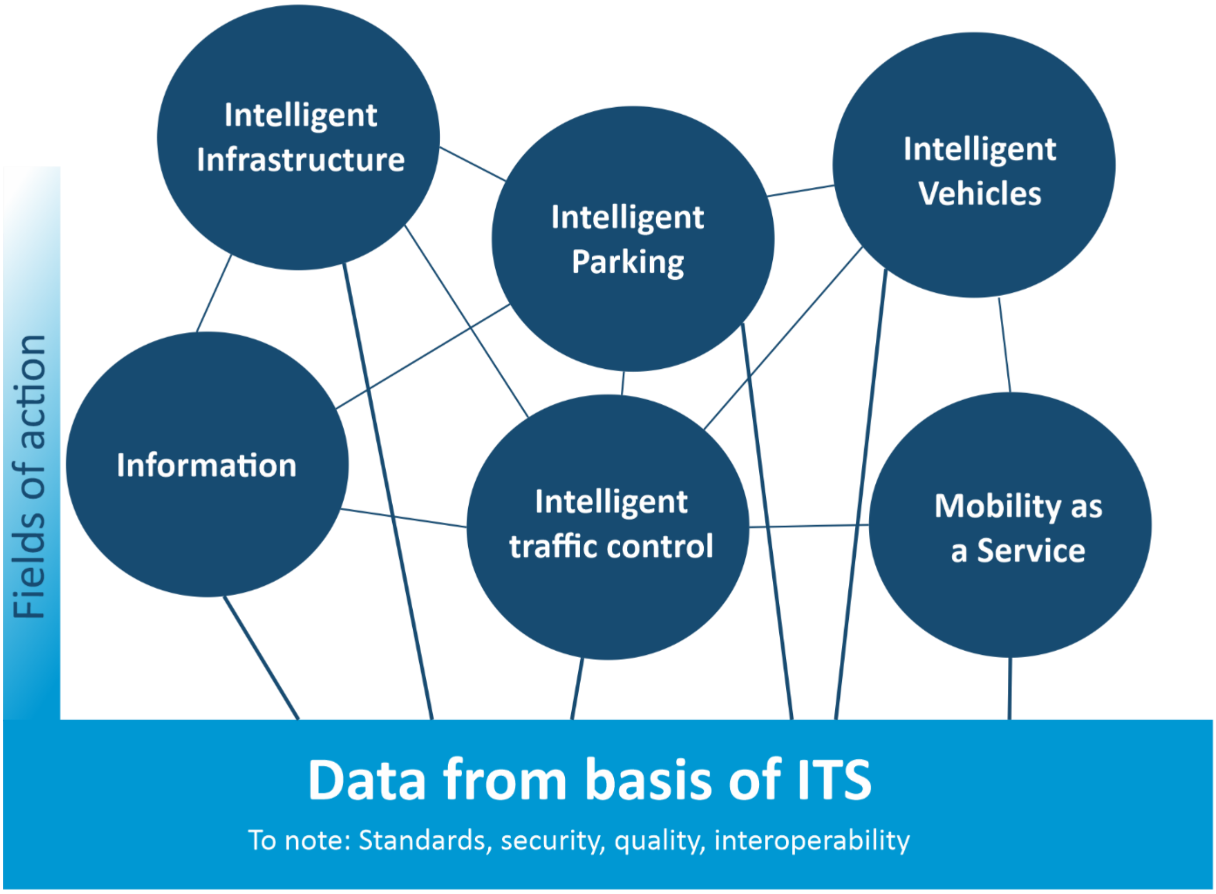

Figure 5: Fields of action of the ITS-Strategy Hamburg (source: own illustration, Planersocietät)

To be able to implement the objectives described and at the same time address challenges, the strategy is based on the following six fields of action:[20]

- Data and information
- Intelligent traffic control and guidance
- Intelligent infrastructure
- Intelligent parking
- Mobility as a service
- Automated and connected driving Daten und Information

[20] Bürgerschaft der Freien und Hansestadt Hamburg (2018): 9 cont.

Ensuring data protection and data security plays an overriding role in all fields of action. In addition to motorized road traffic (cars, trucks, buses), the fields of action also include rail-based traffic and bicycle traffic.

Field of action "Data and information "

Reliable databases with agreed standards and technologies are needed for a functioning ITS service. This field of action can be seen as the basis for all other fields of action. In addition to creating the most transparent presentation possible, the focus is on encryption and protection against third-party access and updates. The added value of an ITS system is created when traffic, travel, route, and passenger information from all modes of transportation is compiled and linked to one another. This is the task of the field of action. In Hamburg, the Urban Data Hub Hamburg is in charge of integrating and networking standardized data. In the future, data and information are to be condensed. This can involve the following aspects, among others: Infrastructure data, data on construction sites, vehicle numbers or stop, timetable and tariff information in public transport.

The interim goal for 2021 is expanding the urban platform, which ensures the required ITS framework architecture. The integration of dynamic and static traffic data into this still has to take place. The same applies to providing all ITS-relevant data and information via a standardized interface for internal and external users.

Field of action "Intelligent traffic control and guidance "

A traffic management system is the main component for controlling and handling traffic. Classical designs are traffic and network control systems, traffic signal systems, and traffic control centers, whereby the public authorities direct the traffic in a targeted manner. A prerequisite for intelligent traffic control is that vehicles have the necessary technology to communicate with the infrastructure. This applies not only to motorized traffic but also to bicycle traffic.

The technical basis for cross-modal control and guidance of road users is currently being implemented so that initial experience is being gained. For example, 50 traffic signal systems are already communicating with motorized and non-motorized road users. Almost 750 traffic signal installations are equipped with detectors for lane-accurate traffic counting. By 2030, the traffic volume is to be differentiated in real-time according to the traffic lane. In addition, access to 95 percent of all traffic-relevant data for network control and public transport influence is to be guaranteed. In addition, the entire infrastructure will be capable of direct communication with road users.

Field of action "Intelligent infrastructure "

Intelligent infrastructure can detect external influences and processes through systems and sensors and communicate these digitally in real-time. The field of action includes all equipment and components as well as all accessories that enable V2X communication. The basis for this is mobile communications and WLAN infrastructure. Up to now, it has not been possible to guarantee nationwide mobile communications along the federal autobahns. Initial practical experience shows that the expected data volume will be small compared to streaming services.

Currently, all elements of the technical infrastructure are connected to a higher-level management system. This is used to monitor the operating status or to identify errors and collect data. By 2030, transmission is to take place in real-time. Furthermore, the road infrastructure will be expanded to provide the necessary communication technology for automated/autonomous driving. This includes protective devices with reflectors, unique signs, sensors (radar, laser, LiDAR), and cameras. Standards have not yet been defined for this.

Field of action "Intelligent parking "

Parking pressure in major cities continues to increase, and Hamburg is no exception. This can be counteracted with a holistic parking management system with good information distribution about available parking spaces. Parking management can be used for classic parking garages and park and ride and bike and ride facilities. There is an essential interface to Mobility as a Service because if an intermodal mobility offer with integrated apps is created, the free parking space can be displayed directly. In this way, parking search traffic is reduced in depth along with traffic-related emissions. Ideally, this occurs with a Germany-wide app. Otherwise, it is possible to link the data of the free parking spaces directly with the destination navigation of the car. This form of intelligent parking management must not be offered on a provider-specific basis.

The interim goal for 2021 is to identify and commission technologies for parking space occupancy forecasting and utilization control. The data will be available to the Urban Platform. Furthermore, integration into the mobility platform hvv switch is planned.

Field of action "Mobility as a Service "

Mobility as a Service (MaaS) looks at the mobility needs of road users from as many different perspectives as possible. The goal of MaaS is to enable all road users to travel as comfortably as possible, regardless of their choice of vehicle. In addition to individual motorized transport, the focus is on public transport and innovative forms of mobility such as ride or car sharing. The focus here is on the users. In Hamburg, this field of action is reflected above all in the digitization of public transport (e-ticketing) and the hvv switch points. MaaS can be successful because barrier-free access is made possible via a platform, whereby all mobility offers, tariffs, timetable information, and payment options are mapped.

The mobility platform hvv switch has already been completed. A comprehensive range of mobility services, including on-demand services, has been integrated. The goal by 2030 is to provide a holistic, multimodal, and digital mobility platform. This platform will provide information about intermodal and multimodal mobility offers across all providers. To this end, public and private providers must cooperate. In this way, the share of public transport in the modal split will be increased overall.

Field of action "Automated and connected driving "

System-assisted or future autonomous driving can significantly increase road safety. Further research is required for automated or autonomous driving in urban areas due to numerous environmental influences. Nevertheless, autonomous vehicles will become part of everyday mobility in the current decade. In addition to the technical issues, legal questions must also be answered. Overall, automated and autonomous driving should increase traffic safety and traffic optimization, thereby reducing environmental pollution.

Currently, test routes have already been set up in public spaces used by highly and fully automated vehicles across all providers to date (S. Projekt HEAT in Kap. 2.3). By 2030, Hamburg's infrastructure will meet the required standards for automated and autonomous driving. Furthermore, a section of Hamburg's U5 subway line will be operated autonomously. In addition, public transport and IV vehicles are autonomous or fully automated.

2.3. Selected projects

With 172 ITS-relevant projects (90 active, 55 completed, 18 in preparation, and 9 activities), the Free and Hanseatic City is one of the pioneers in ITS application in Germany. The projects are brought together centrally by a monitoring tool. Of these 172 projects, 42 were selected as so-called anchor projects because they significantly impact the achievement of the ITS strategy and provide an essential basis for further ITS projects. In the following, some of the projects are first listed in clusters according to the fields of action before individual projects are outlined in more detail. These may currently still be in the planning stage or have already been completed.

FIELD OF ACTION	PROJECT
DATA AND INFORMATION	• aVME (automated traffic volume measurement) • HaRaZäN (cycling counting network for Hamburg) • ROADS (Intelligent construction site management)
INTELLIGENT TRAFFIC CONTROL AND GUIDANCE	• PrioBike HH ("Green wave "for cyclists by detecting cyclists in real-time using thermal imaging cameras) • Green4TransPORT (Intelligent traffic light control with flexible adaptation to the traffic) • BiDiMoVe (Prioritization of buses at traffic signals)
INTELLIGENT INFRASTRUCTURE	• Hamburg Box (Smart Locker – Parcel delivery on the track) • I2PANEMA (Development of IoT in the port area) • HyperPort Cargo Solutions (Hyperloop in the port)
INTELLIGENT PARKING	• SmaLa (Smart loading area) • Digital parking
MOBILITÄT AS A SERVICE	• On-Demand-Shuttle (IOKI) (Ridesharing-services) • Hvv switch
AUTOMATED AND CONNECTED DRIVING	• HEAT (Test operation of autonomous minibusses) • Medifly Hamburg (Drone as medical air cargo service) • Test track AVF Hamburg (for autonomous and connected driving) • RoboVaaS (Unmanned surface and underwater vehicles in port)

Figure 6: Selected ITS-projects in Hamburg (source: own illustration, Planersocietät)

Cargo 24/7

The Cargo 24/7 project is assigned to the "Data and information" field of action. The project should lead to a shift of transport times to less traffic (from about 5 p.m.). On the one hand, this will result in a change in heavy-load traffic; on the other hand, other companies involved in the transport chain will have to adapt to the new situation. Due to the resulting traffic equalization, it is hoped that the performance of the port will increase. The slot booking systems between the port terminal and the logistics hotspots in the hinterland will be integrated into one system and can thus be coordinated. In addition to more efficient transport chains, lower emissions and reduced driving time violations are other hoped-for positive effects of the project[21].

Figure 7: Hamburger Hafen (source: Logistik-Initiative Hamburg)

ESM

The environmentally sensitive traffic management measures (ESM) are assigned to the second field of action, "Intelligent traffic control and guidance". Here, all traffic-relevant data for the urban traffic control centers are brought together in an integrated presentation. The advantage of the central system is that it provides an overview of the entire city to derive specific measures for various scenarios. These scenarios include, for example, the rerouting of traffic flows through traffic signals, changes in green phases to the detriment of traffic flow on side streets, or targeted speed reductions to increase capacity. At present, Hamburg lacks the technical prerequisites for implementation. The necessary information is held by various authorities and must be compiled in a central control center[22].

[21] Logistik-Initiative Hamburg (o.J.) & Bürgerschaft der Freien und Hansestadt Hamburg (2018): 14
[22] Bürgerschaft der Freien und Hansestadt Hamburg (2018): 20

HEAT

Figure 8: Teststecke HEAT (sourcee: BWVI)

The abbreviation HEAT (Hamburg Electric Autonomous Transportation) stands for an automated (later possibly even autonomous) electric public transport minibus that runs on a predefined circular route between the Outer Alster and the Elbe with essential stops in between (e.g., Dammtor, Messehallen, St. Pauli, Landungsbrücken). In 2021, fully automated operation at speeds of up to 50 km/h is realized. The project is assigned to the "Automated and connected driving" field of action.[23]

HVV SWITCH

Figure 9: hvv switch-Punkte (source: Nahverkehr Hamburg)

The mobility platform hvv switch is assigned to the field of action "Mobility as a Service". At the so-called hvv switch points, a multimodal transport offer consisting of the StadtRAD and various car-sharing providers is provided. The points are clustered at subway and S-Bahn stops. Over 1,500 vehicles (from car2go, DriveNow, cambio) and 2,500 StadtRAD bicycles are offered at more than 70 locations. Hvv switch offers multimodal transportation planning. To further interface with public transport, switch was planned into the app of the Hamburg transport association. In June 2020, hvv switch replaced the previously known brand swithh. So now, in addition, hvv tickets can be purchased via the app, as well as book and pay for rides with the ride-sharing service MOIA. The integration of SIXT, MILES Mobility, and ioki is planned, and coordination with SHARE NOW, WeShare and Hansa-Taxi are also underway[24]. The goal is to have more than 300 hvv switch points installed in Hamburg by 2030.

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[23] HOCHBAHN (2021)
[24] hamburg.de (2021)

3. ITS potential analysis of various locations

The development and utilization structure in the district of Altona is diverse and ranges from urban character and large housing estates to commercial and industrial areas. Thus, different traffic loads are triggered in the respective types of space due to other trip purposes and causes for the emerging mobility - there are differentiated conditions for sustainable mobility. The general goal is to analyze the purposes of travel and the causes of mobility in the following study areas and then to use ITS-supported measures to achieve a modal shift to environmental transport. Thus, to present exemplary concept modules for establishing innovative ITS systems in mobility, three differentiated urban space types with different requirements and needs for mobility (see excursus box) are analyzed in more detail and subsequently considered in the ITS potential analysis. The study areas are:

- Teufelsbrück (as a bottleneck for commuters with the particular transfer to the ferry)[25]
- Mitte Altona (as a new urban mixed-use area with a surplus of uses)
- Schnackenburgallee (as a industrial and commercial location with deficient public transport accessibility)

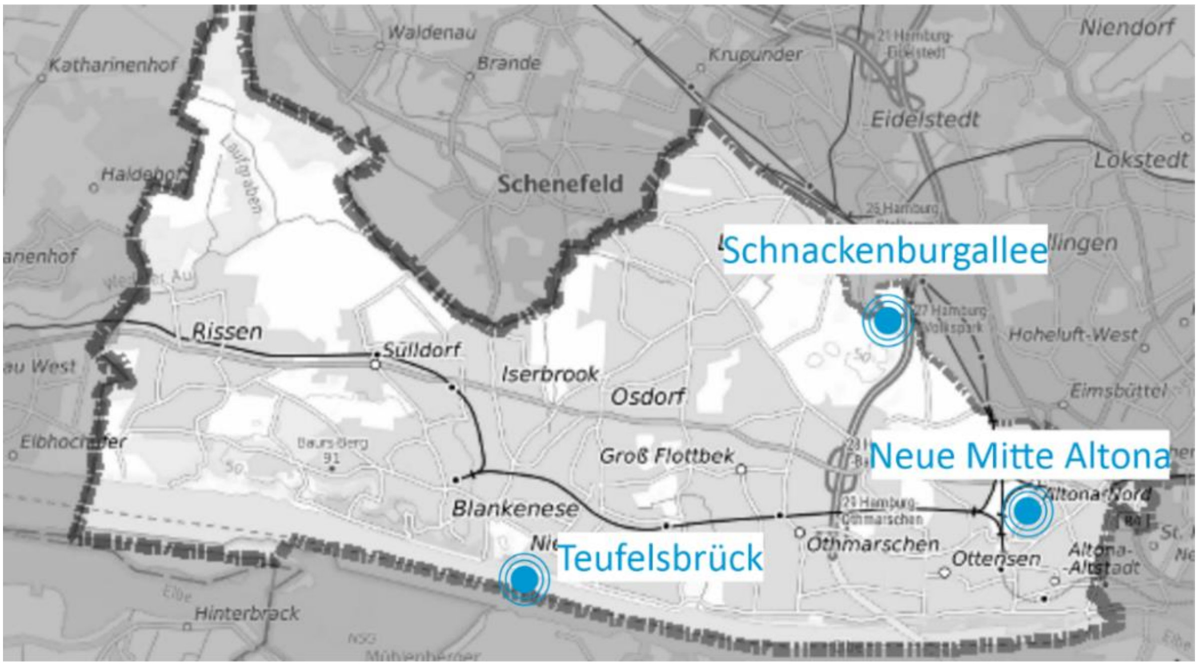

Figure 10: Area of investigation (own illustration, Planersocietät) Even though each study area has its character, structural parallels can be drawn to similar city or neighborhood typologies. Thus a transferability of measure modules for the establishment of ITS systems is likely be established. This is true even though the study areas have different characteristics. These are to be supported with the help of ITS systems.

[25] As part of the HUPMOBILE project, the report on Mobility as a Service deals with the bottleneck of the Alter Elbtunnel. The popular commuter route between Wilhelmsburg and Altona/St. Pauli is also heavily congested by cyclists on weekdays.

Differences in mobility needs/requirements differentiated according to spatial typologies

For the implementation of an ITS strategy, a more detailed analysis of the spatial types to be found in a municipality is required. In this context, the main focus is on the purposes of travel and the causes of mobility and traffic, in order to subsequently prevent these by means of ITS or to generate a modal shift. Therefore, the investigation of the reasons for traffic induction is elementary: What exactly causes traffic in the individual areas and how can ITS make it more sustainable and contribute to a modal shift?

Bottleneck

A traffic bottleneck occurs where the traffic infrastructure is overloaded at certain times due to the massive number of traffic participants. This is often a traffic junction that is used by employees at the beginning and end of work on weekdays. The goal of ITS solutions is to relieve the traffic bottleneck with digital measures so that users are guided smartly through the traffic.

New urban mixed neighborhood

An urban mixed-use neighborhood can be characterized by a high building density with high diversity. The core functions include living, working, local supply, public and cultural facilities as well as leisure activities. Furthermore, this type of urban area is characterized by short distances due to the transport infrastructure. This type of urban area, which is mainly characterized by a young population, generally has a high population density. Due to the growing online trade, the volume of delivery traffic is increasing here in particular, which is also being expanded by the retail trade. Short distances and a shortage of space determine everyday mobility. The issue of last-mile logistics must be taken into account at the outset in the context of the new development of the neighborhood. The aim of ITS solutions is to better coordinate the various traffic-related usage requirements and thus reduce traffic congestion and increase the quality of life and stay.

Commercial and industrial area

In business parks, which in many cities are decentralized with good highway access, commercial traffic and the employees' commute to work are considered the main sources of traffic and mobility. Often, large employers are located in business parks, attracting workers from the surrounding areas. Due to the location of the area and the lack of mobility alternatives, these employees are often dependent on their cars. The goal of ITS solutions in business parks is, on the one hand, to guide delivery traffic smartly through the area and, on the other hand, to achieve a modal shift to the environmental network by identifying (and creating) mobility alternatives (car sharing, ride pooling, e-bike sharing) with the help of digital links. Employees should be offered a wide range of mobility options. The basis for this is a well-developed pedestrian and bicycle infrastructure in business parks.

3.1. Spatial division of the areas of investigation

The spatial division of the study areas serves to characterize them on the one hand and to explain the existing mobility offers on the other. These refer primarily to the offers of the environmental network, as this will be the focus of the subsequent ITS-supported measures to be implemented.

3.1.1. Teufelsbrück

At the Teufelsbrück site, the ITS potential analysis is carried out in the context of a possible mobility interface. The study area is located west of the Elbe beach and on the southern edge of Jenischpark in Hamburg Altona. The Elbchaussee leads to Teufelsbrücker Platz, which was redesigned in 2009. On the one hand, Teufelsbrücker Platz is a popular excursion destination. On the other hand, it is the starting point for numerous employees of the Airbus company, who reach the company premises directly via the ferry dock. On weekdays, this creates a traffic bottleneck due to the rush-hour traffic of many employees of the industrial area on the other side of the river Elbe.

Figure 11: Teufelsbrücker Platz (source: hamburg.de)

PT

Teufelsbrück is served by six bus lines and three harbor ferry lines within the Hamburg Transport Association (HVV). Bus lines 21 (destination: Osdorf, runs on weekdays between 05:00 and 22:50 every ten minutes, from 22:50 to 23:50 every 20 minutes), 111 (Elbchaussee - Bahnhof Altona - Reeperbahn - Landungsbrücken, runs on weekdays between 6:30 and 23:09 every 20 minutes), 112 (from Blankenese to Altona and Hamburg Hbf, runs on weekdays from 05:41 to 00:01 every 20 minutes), 286 (from Blankenese to Bahrenfeld, runs every half hour on weekdays between 05:30 and 23:00), 392 (Hamburg Airport, runs every half hour on weekdays from 06:03 to 20:33) and, in addition, to rush hour, X86 (Altona station, runs eight times an hour on weekdays between 05:37 and 18:31, then more irregularly). Consequently, the Teufelsbrück stop is served by an average of 28 buses per hour on a working day between 06:30 and 18:30. In addition, the port ferry lines 62 (Landungsbrücken, so-called "Lumpensammler") also serve the Teufelsbrück stop. "64 (to Finkenwerder, runs every half hour on weekdays between 05:17 and 06:47, every quarter-hour between 07:05 and 08:47, every 30 minutes between 08:47 and 14:47, every 15 minutes between 14:47 and 18:17, and every 30 minutes between 18:17 and 20:47 every 30 minutes) and 68 (Airbuswerk, runs on weekdays between 05:30 and 09:30 eight times an hour, between 12:40 and 15 four times an hour, between 15:00 and 18:00 again eight times an hour and after 18:00 until 21:30 on average every half hour) the study area. In general, Teufelsbrück is thus well served by public transportation in all directions of Hamburg. At the site, there is a redistribution from various means of transport to regular commuter ferry.

Local mobility

Teufelsbrücker Platz is an attractive place to spend time. In addition to the Elbchaussee, the study area is also accessed via the Hans-Leip-Ufer cycle path running parallel to it. This leads across the Elbstrand futher down District of "Mitte" to the Old Elbe Tunnel. So this cycle route provides an important east-west connection between the two bottlenecks Old Elbe Tunnel and Teufelsbrück. In addition, it is also an important tourist connection to the city centre of Altona. Numerous existing bicycle hangers enable safe parking of the bicycle at the ferry terminal.

3.1.2. Mitte Altona

At the location Mitte Altona, an ITS potential analysis is carried out in the context of a residential zone with a surplus of uses. The study area represents a very diversified, lively, and compact space in the sense of the city of short distances, which has a supra-regional catchment area and fulfills a wide variety of usage requirements (residential location, place of work, leisure activities, supply location, tourism, etc.). Altona-Mitte is characterized by dense development and numerous stores and is therefore heavily used by stationary motor vehicle traffic and parking search traffic.

Figure 12: Visualisation of Mitte Altona (source: André Politiers)

PT

The train accessibility of the core area can be classified as very good. The S-Bahn lines S1, S2, S3, S11, S21, and S31 run at five-minute intervals from Altona station. The stops are within walking distance of almost all areas in Altona-Mitte. The Ottensen S-Bahn station, which is currently under construction, will improve the S-Bahn network and accessibility for the core area. In the future, the relocation of Altona's long-distance and regional train station to Diebsteich must be taken into account. The accessibility of bus transport can also be rated as good. Numerous bus lines (including the Metrobus lines M1 (Alster Chaussee) and M2 (Schenefeld) serve the core area. The bus station at the Altona train station is the hub of most bus lines.

Local mobility

Parts of Mitte Altona are attractive areas for pedestrians. In the future, cycle routes 1 and 13 will run through the core area, which means that many sites have already been redesigned for cycling. However, the general cycling infrastructure still has considerable spatial deficits and diverges significantly in terms of guidance and condition.

Sharing-Mobility

The core area of Altona offers a large number of dispersed multi- and intermodal interfaces from public transport to the environmental network and provides a wide range of sharing services. Numerous mobility stations (hvv switch) with different offers (stationary and free-floating car sharing, [cargo] bike rental StadtRAD, B+R, etc.) are available in the study area. The stationary car sharing of Cambio is also available outside the hvv switch station at its stations with different vehicle types. The free-floating car-sharing service of ShareNow covers the entire study area. However, there is a lack of secured or reserved parking spaces in highly frequented areas (e.g., around Altona station). Ride-sharing services are represented in the study area by the providers MOIA and IOKI. E-scooter sharing is available throughout the study area.

3.1.3. Schnackenburgallee

Schnackenburgallee runs through the commercial area of the same name, which is home to over 1,400 companies with around 12,000 employees. This makes the place the third-largest commercial and industrial park in Hamburg after the port and Billbrook.

Figure 13: Current Condition of the Schnackenburgallee (own illustration: own photos, Planersocietät)

Schnackenburgallee is located in the west of the Altona district, near the BAB7 motorway. Schnackenburgallee has different spatial characteristics: The northern area is mainly mixed commercial, partly with small-scale business and numerous green structures.

The central area between the freeway and the green corridor has a predominantly commercial character with wide but partly green street spaces. The area south of the highway is commercial and industrial with wide street spaces. The development for motor vehicle traffic can be assessed as very good. Due to the feeder function of Schnackenburgallee to the BAB7, the area under consideration is well connected to the supra-local road network.

PT

For access to the Schnackenburgallee commercial area, the most important stops are Eidelstedt (S-Bahn line 1 with the option of changing to AKN line 1 [Eidelstedt-Ulzburg-Neumünster]) from the north and Diebsteich (future long-distance train station) from the south. The southern part of Schnackenburgallee is not accessible on foot by subway and/or commuter rail (radius 600 m). So the accessibility of bus transport can be rated as average. With a catchment radius of 400 m, the bus lines 22 (10-minute intervals during the rush hour, with additional trips), 180 (20-minute intervals), and 288 (hourly) ensure the best possible accessibility. The subway line 5, which will run to the Volkparkarena, is expected to be completed by 2030 to be a further connection here.

Local mobility

So far active mobility has played a subordinate role due to the commercial character of Schnackenburgallee. Bike routes 2 (City-Eidelstedt) and 14 (Äußerer Ring) tangent the study area to the northwest and northeast, respectively. Overall, the bicycle infrastructure is in poor condition: there are gaps, there are no crossing possibilities, and some bike paths are very narrow. Although the S-Bahn station Stellingen has an excellent local mobility connection to Schnackenburgallee with the green axis, itis not optimally integrated into the cycling network and has design and functional deficits.

Sharing-Mobility

There are no stationary car-sharing services in the Schnackenburgallee study area. The nearest station of the provider Cambio is located near the Langenfelde stop and is difficult to reach from the magnifying glass area due to the barrier effect of the railroad tracks. The southwestern part of the highway BAB 7 is in the business area of the free-floating provider ShareNow. Ride sharing is available in the study area with MOIA (complete business area) and IOKI (spatially narrow northwestern subarea).

The surrounding S-Bahn stops (Eidelstedt, Stellingen, Langenfelde and Diebsteich) are equipped with official B+R (Bike and Ride) stations. The P+R station Elbgaustraße is located about one kilometer away. Mobility stations (hvv switch) are not available.

The conclusion in the case of Schnackenburgallee is that the PT and AM infrastructure is being improved here. It is important that the area is developed equally for all road users and is not only designed for IMT.

3.2. Challenges and potentials for sustainable ITS-supported mobility in the study areas

Based on the different types of urban areas, the additional mobility caused by them, and the mobility offers shown in each case, different potentials and challenges, which are in the immediate context to the following measures and fields of action, are shown in the individual study areas.

Teufelsbrück

The Teufelsbrück study area is a traffic bottleneck on weekdays due to industrial area employees, e.g. huge employees like Airbus, arriving and departing. In terms of time, this is strongly pronounced in the morning hours (05:30-10:00) and the afternoon (15:00-17:00). Thus, on the one hand, the disentanglement and equalization of the prioritized choice of means of transport - bus and car - and, on the other hand, the identification of new possible mobility alternatives represent the most significant challenges in the Teufelsbrück study area. These challenges are to be solved with ITS-supported systems.

Mitte Altona

In the Mitte-Altona, there is a high traffic volume during the day due to the numerous road users resulting from the various uses in the study area. This is characterized by parking search traffic, delivery traffic, and increasing demands of cyclists and pedestrians on the public space. With the help of ITS-supported developments, these needs are to be better coordinated and conflicts solved as they arise. The goal is to achieve a high quality of stay in the public space through less traffic.

Schnackenburgallee

Schnackenburgallee is currently dominated by motor vehicle and heavy goods traffic. The lack of minimum widths and crossing situations make the use of bicycles unattractive. The existing offer of local mobility and sharing mobility is not in context with each other. The challenge in the Schnackenburgallee study area is to use ITS structures to ensure good accessibility, both by bicycle and public transport, and to anchor new mobility alternatives. This refers to the networking of traffic light phases with buses or data of road users generated via the hvv switch app. Thus, numerous potentials can be derived from the existing challenges regarding the use of ITS systems.

Addition: Employee survey Schnackenburgallee

For a better assessment of the mobility requirements of the employees of the companies on Schnackenburgallee, the employee survey conducted between November 2020 and February 2021 as part of the "Climate protection sub-concept Mobility in Altona" is used. Thus, among other things, the personal mobility requirements, which are of high importance for the determination of the ITS potential analysis for the industrial and commercial location Schnacken-burgallee, were determined: Currently, there is low access to HVV season tickets (30 percent), car sharing offers (12 percent), the StadtRad (14 percent) or e-scooters (7 percent). A detailed look at the evaluation of the 87 users of carsharing services shows that 86 percent prefer free-floating forms, only five percent station-based providers and nine percent both forms. Currently, the commute to work is primarily made by car. Thus, 55 percent (in summer) drive to work by car (almost) every day (n=684). Only 20 percent(n=686) use the train and only 10 percent (n=686) the bus for their daily commute. The remaining percentage points are split between biking and walking.

Furthermore, the survey shows that intermodal design of the commute to work is not widespread. Only 20 percent (n= 711) use different modes of transportation to get to work. Of further interest for ITS-based measure development is that 58 percent (n=483) of the respondents cited poor public transport connections as the most common reason for MIV use. In particular, bus connections (frequency), the density of the bus line network and the coordination of travel times of different lines were rated as rather poor or poor. 642 people who took part in the survey indicated which potential services they would find good in the future. In addition to bike routes, the most popular options here are an area-based shuttle service, a neighborhood bus, more bike parking facilities in public spaces, ridesharing and bike&ride services. This will be followed by StadtRad stations, carsharing free-floating services and a platform for inter-company car pooling.

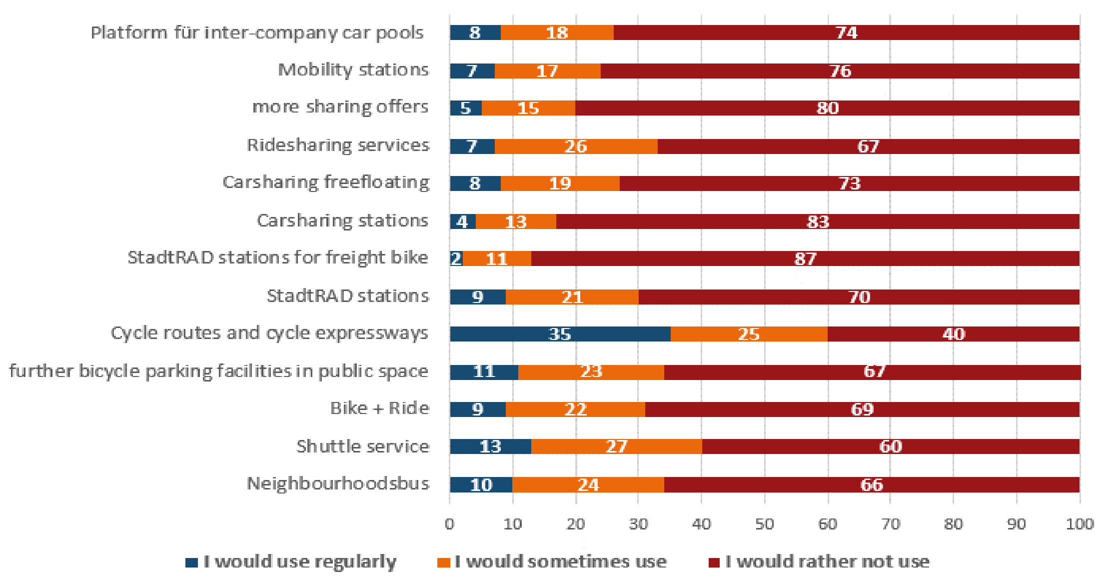

Figure 14: Potential mobility services for Schnackenburgallee (source: own illustration, Planersocietät)

4. Derivation of fields of action and measures

Based on the potential analyses of the three space types

- **Bottleneck:** Teufelsbrück as an occupational bottleneck, with a lack of mobility alternatives to public transport
- **Urban mixed neighborhood:**Mitte Altona as a residential, working, local shopping and recreation area
- **Industrial park:** Schnackenburgallee as an arrival and work location for employees and delivery traffic

various fields of action and measures can be derived. This is done concerning mobility interfaces at the Teufelsbrück site, city logistics and neighborhood mobility in Mitte Altona, and mobility management and mobility alternatives at Schnackenburgallee. In total, six different fields of action can be defined, which are based on the fields of action of the Hamburg ITS strategy (except for Intelligent Logistics). These, in turn, give rise to different measures.

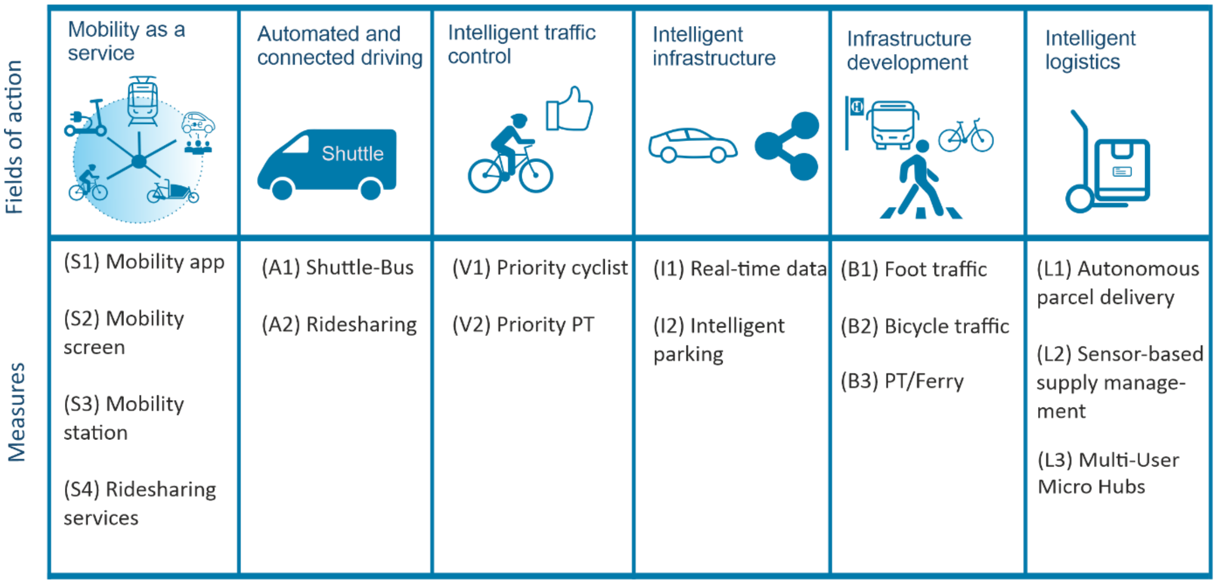

Figure 15: ITS field of action and measures (source: own illustration, Planersocietät)

4.1. Teufelsbrück

The Teufelsbrück study area is currently a bottleneck in Hamburg Altona with high traffic congestion at certain peak times. Since it is a mobility interface, especially with the unique feature of the ferry, the pilot area offers numerous attractive potentials for intermodality using an implementation of integrated ITS systems. In general, Teufelsbrück requires an expansion of the current transport services so that the employees of the industrial and commercial companies are offered various options. Overall, the fields of action in the study area are *Mobilität as a Service (S)*, *Intelligent infrastructure (I)* und *infrastructure development (B)*.

S1 Mobility-App – hvv switch

The general goal of the Hanseatic City of Hamburg is to establish a holistic, multimodal, digital mobility platform that provides information about intermodal and multimodal mobility offers across providers, and that can be used to plan, book, and pay across providers. The Finnish mobility app Whim, which was first tested in Helsinki and is now used sporadically worldwide (Vienna, Turku, Antwerp, West Midlands), represents the best-practice example. In Helsinki, the mobility offer is most diverse with public transport, cabs, car sharing, e-scooters, city bikes, and Sofia[26]. In Finland, the necessary regulations for data protection and the transparency of the collected data are already in place. This is currently not the case in Germany. In Hamburg, the hvv switch app provides an excellent basis since it can already be used to book hvv tickets or other forms of mobility (MOIA, StadtRAD, ferry) via a uniform billing service.

Nevertheless, not all providers are represented. There is also the problem that numerous employees from neighboring municipalities and districts commute to Teufelsbrücker Platz. Here, the app could reach its limits due to the different fare zones and transport associations.

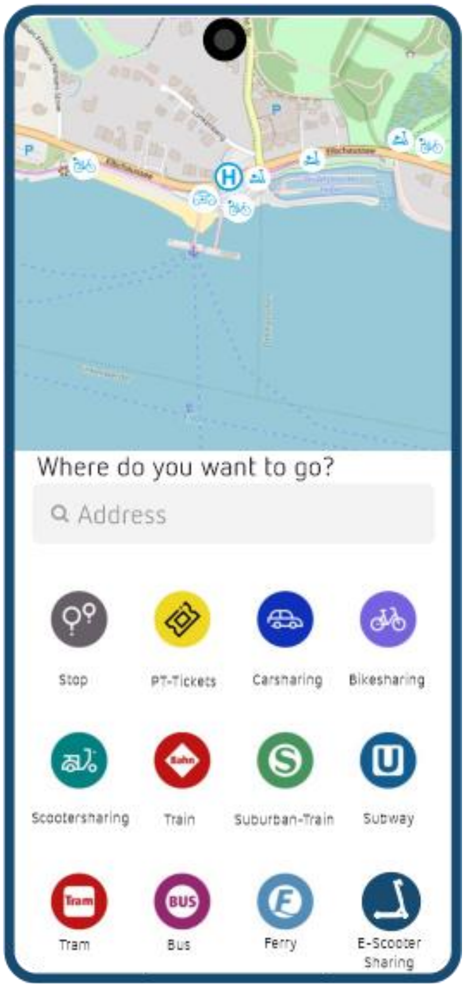

Figure 16: Mobility-App - Location Teufelsbrück (source: own illustration, Planersocietät)

[26] Sofia is a co-working space in Helsinki. In addition to individual work, it is also possible to hold meetings or lectures. The service has been integrated into Whim, so that with certain subscriptions a free day a month can be booked at Sofia.

In the Teufelsbrück case study, the mobility app and platform is intended to be particularly helpful for employees of the companies in the area in planning their daily commute to work. The primary goal is to link different forms of mobility, i.e., between conservative means of transport (bicycle and bus), innovative new mobility services (ride pooling), or other forms of sharing (especially car sharing in the free-floating system), to facilitate route planning. Thus, planning the upstream commute to and from the ferry, which significantly shapes it, is simplified by displaying multiple options in a user-friendly way. With the help of the mobility app, the resulting traffic due to the commute is specifically mitigated by ITS-based measures on the one hand, as mobility alternatives are shown. On the other hand, a basis for a modal shift is provided. For sustainable use of the app by the employees, a workshop day is recommended for introducing the app.

S2 Mobility-Screen

A mobility screen is to be installed at the bottleneck Teufelsbrück. Up-to-date and reliable traffic information makes an essential contribution to supporting road users in their mobility decisions. The most significant added value is created when traffic, travel, route and passenger information, and information about disruptions or schedule deviations can be linked and displayed for as many forms of mobility as possible. Using the example of Teufelsbrück, this could be implemented to transport ferry, bus, car-sharing car, bicycle and StadtRAD. The mobility screen thus visually displays various

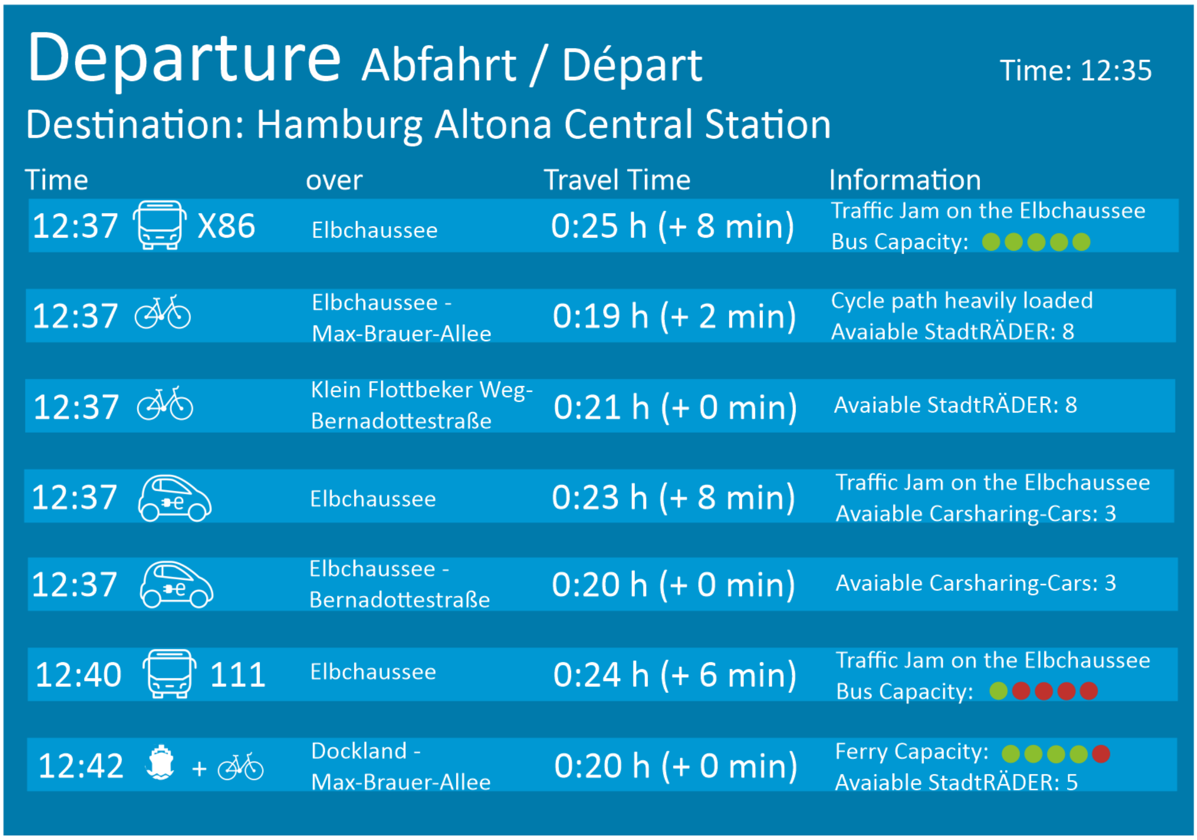

Figure 17: Mobility-Screen Teufelsbrück (source: own illustration, Planersocietät)

mobility options with essential destinations. This applies, among other things, to Altona-Mitte (Altona Bahnhof), Bahrenfeld and Blankenese with other important intermediate stations. On the other hand, information such as bus delays, bustling routes, accidents, traffic jams, weather conditions, etc., are taken into account in real-time when calculating travel times to the various destinations and visually displayed on the mobility screen.[27] In this way, users can choose their route and form of mobility for the way home, depending on their preferences, time constraints and available means of transport. The aim is to avoid highly congested routes in rush hour using the most environmentally friendly means of transport possible.

S3 Mobilitäty hub/hvv switch-Punkt

There is already a StadtRAD station near the Teufelsbrück ferry terminal. To bundle the already existing mobility offer even better, a hvv switch point would be a good idea. The nearest hvv switch points are located at Alter Fischmarkt so that further points in Othmarschen (east of Jenisch Park) should be established to provide a comprehensive network. The basis of this mobility station should be the leading equipment of a hvv switch point with car-sharing providers. In addition, the StadtRAD will be integrated into the station as well as other sharing offers, such as e-scooters. The station at Teufelsbrück will provide employees with a comprehensive mobility offering in the future.

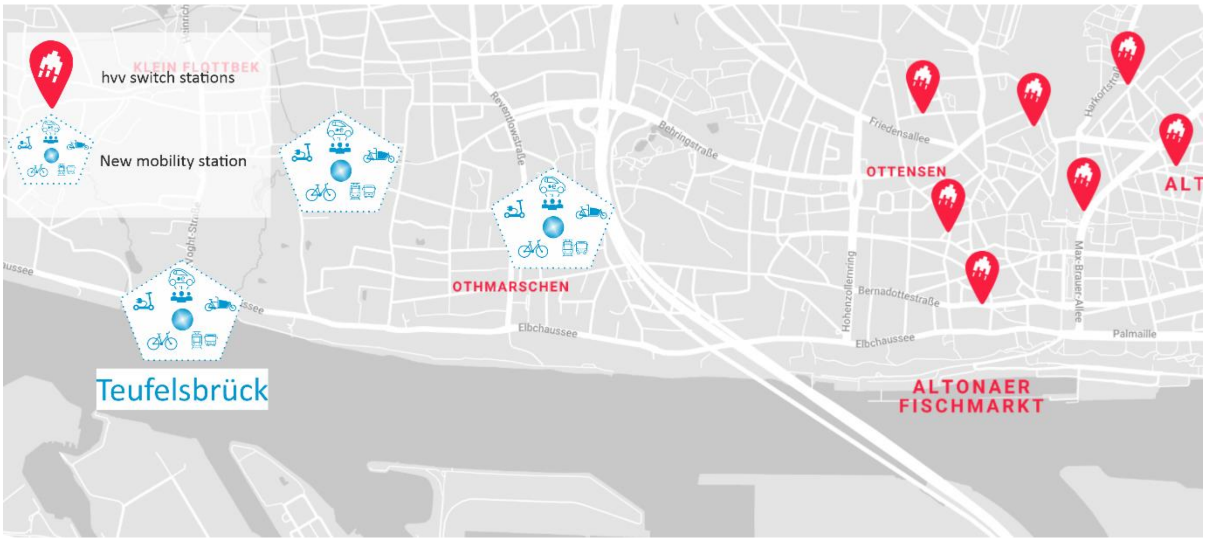

Figure 18: Locations of hvv switch-points (source: own illustration, Planersocietät after hvv-switch.de)

The hvv switch station is directly connected to the mobility screen and the mobility app. The three measures listed here individually must be seen as a closely linked construct. Here, too, freely available StadtRÄDER (city bikes) or the number of available car-sharing cars are transmitted in real-time. Employees use the app to book their means of transport for the journey home, which they choose according to personal preferences, availability, and weather conditions. Furthermore, users can drop off their packages at the station or have them delivered to it. By concentrating delivery traffic at this peripheral location in Altona, additional delivery traffic to residential areas is avoided. In addition, a

[27] In particular, the congestion forecast is intended to calculate the most accurate travel time extension possible based on live data and historical congestion data as well as planned construction measures that are linked together.

mobility survey of Airbus employees seems to make sense. Especially at the most frequent residential locations, the installation of a hvv switch point can provide an alternative mobility offer. Only with an area-wide network of hvv switch points can a long-term switch away from the private car to multi and intermodal route planning be realized.

I1 Real-Time Data

The elements of intelligent transport infrastructure are being established at the Teufelsbrück site. For example, counting stations transmit the current passenger numbers on the ferry in real-time to display the free capacity via the mobility screen. Other interesting aspects that can also be recorded by counting stations and integrated into the mobility screen are freely available city bikes and the number of unoccupied bicycle parking spaces. In addition, a permanent counting station for cyclists will be set up. In this way, current traffic volumes can be recorded in real-time. Based on this data, an up-to-date traffic situation, as well as reliable and time-of-day-dependent traffic planning data, can be derived.

B3 Ferry-Route

For the Hamburg ferry to be competitive with the car and even provide a faster connection to the center of Altona via the Alter Elbtunnel pier, the replanning of the current ferry routes represents potential. There is no direct connection between Teufelsbrück and Alter Elbtunnel, so the travel time, which is over 30 minutes, is unnecessarily extended by a change in Finkenwerder. With a direct connection between the locations, a travel time of fewer than 15 minutes is possible. In the future, the ferry will represent an attractive mobility alternative in Hamburg Altona between the Alter Elbtunnel and Teufelsbrück piers.

4.2. Mitte Altona

The area under investigation, Mitte Altona, is heavily burdened with traffic due to a surplus of uses. In this study area, ITS-supported measures must be used to change regular traffic routes innovatively. In addition to the fields of action in the study area, the following areas of action will be investigated: *Mobility as a Service* and *Intelligent infrastructure,* and *intelligent logistics*. The construction measures of the quarter bring with them extensive scope for the redesign of logistical processes.

S3 Mobilitäty hub/hvv switch-Punkt

At the beginning of 2021, 79 hvv switch points were in operation in Hamburg. Eighteen are located at bus stops, 61 are distributed decentrally in the neighborhoods. Additional hvv switch points in the New Center of Hamburg-Altona can reduce private car use. A representative survey by the Technical University of Hamburg shows that this is possible with the hvv switch points. In the survey, eight percent of respondents said they had given up their cars because of the new service, while 21 percent said they had consciously decided not to buy a car. The general idea of living without their vehicle is also already firmly established among users. In particular, the conversion of public parking spaces into decentralized switch points met a high level of approval in the survey.

Figure 19: hvv switch points in Mitte Altona (source: own illustration, Planersocietät)

In Mitte Altona, further hvv switch points provide a mobility offer and other services, such as a parcel station, so that there is a demand-oriented, multimodal shared mobility offer. In Altona, too, carsharing remains the main component, as at a usual hvv switch point. In addition, a broad, multimodal range of shared flexible mobility services is to be provided within the neighborhood so that routes and route chains of residents are bundled here. In addition to charging infrastructure, all micro-mobility forms (bike sharing, cargo bike-sharing, e-scooter sharing) and a ride-pooling offer will be established. Here, too, the station is closely related to the app. The difference to the mobility station at

Teufelsbrück or Schnackenburgallee is that the hvv switch points inMitte do not have to be adapted exclusively to the needs of work trips. In the Mitte, leisure routes or routes to local suppliers are also important.

I2 Parking Occupancy Forecast

Parking pressure is also increasing in Hamburg-Altona, as in other cities. Thus, holistic parking management and good information distribution of available parking spaces gain increasing importance. In the new center of Altona, mobility is to be based primarily on pedestrian and bicycle traffic and supplementary public transport services. For residents who are nevertheless dependent on their cars for various reasons, a parking space occupancy forecast and utilization control system should reduce the search for parking spaces and the resulting additional traffic. The same applies to visitors who park in public areas. Information and data on occupancy levels must be provided by the Urban platform. In addition, the management of free parking spaces should also facilitate delivery traffic. Similarly, the occupancy rate is thus communicated to the user digitally and in real-time.

L1 Autonomous Package Delivery

Currently, the innovative and visionary approach of delivering packages autonomously represents an area of potential in Germany. Delivery drones are based on concepts of small autonomous vehicles that are conceivable both in the air and on the road. They are associated with a high level of regulatory effort. Nevertheless, they bring the advantage of zero emissions. At present, the technology has not yet reached the stage where autonomous transporters can operate on the roads. By contrast, numerous pilot projects are already underway with the battery-electric self-driving parcel robots that are to be used on the "last mile." The entire Mitte Altona district is a test area. In addition, parcels can be posted via autonomously operating vehicles. The future scenario nevertheless harbors numerous risks and problems: for example, the parcel robots are limited in terms of their range by the electric drive, the road/walkway surfaces must be well structured, and a high volume of foot traffic automatically leads to increased conflicts. In general, there is a high potential for conflict between the parcel robot and other road users at intersections.

L2 Sensor-supported delivery zone management

Sensor-supported delivery zone management is used to direct delivery traffic in the Mitte Altona in a traffic-friendly manner. Real-time information communicates the utilization and availability of parking spaces to the delivery services. The detectors are connected to the urban platform HH, where the data is prepared, processed, and subsequently sent to the trucks' navigation app.

L3 Multi-User Mikro-Hub

In the measure S3 mobility stations/hvv switch point, integrating possibilities for parcel delivery and drop-off is already mentioned. Here, a general multi-user micro-hub is presented once again. Due to the area characteristics of the urban mixed-use neighborhood, this must be specifically designed for bicycle- or micro-vehicle-based deliveries. An essential feature of these stations must be that it is a provider-neutral (so-called "white label") store. Only in this way can the growing delivery traffic be contained by bundled stations. The bundled parcels are delivered from the regional depot to the micro hub. From here, they are provided by autonomous parcel delivery drivers (L1) or by small electric vehicles or cargo bikes, which are smartly guided through the neighborhood by the sensor-supported delivery management system (L2).

4.3. Schnackenburgallee

Schnackenburgallee is considered a pilot area for ITS-based systems in commercial areas. This shows which ITS-based fields of action and measures can be implemented. In general, Schnackenburgallee requires an expansion of infrastructural facilities, especially for pedestrian and bicycle traffic. In addition, the company survey also shows what potential the employees see. In the Schnackenburgallee study area, the integration of a mobility app, an autonomous shuttle bus service, and targeted mobility stations would appear to make particular sense. Thus, the fields of action of *mobility as a Service, autonomous and connected driving, intelligent traffic control, intelligent infrastructure,* and *infrastructure development* are served.

S1 Mobility-App

The goal is a holistic, multimodal, digital mobility platform that provides information about intermodal and multimodal mobility offers across providers, and that can be used to plan, book, and pay across providers.

In the case study of Schnackenburgallee, the mobility app and platform are intended to serve those working in the area to plan their daily commute. The primary goal is to link different forms of mobility, i.e., between conservative means of transport (bicycle and public transport) and innovative new mobility services (ride pooling, shuttle bus) or other forms of sharing (especially car sharing in the free-floating system) to facilitate route planning. In this way, working people are shown attractive mobility alternatives and their cars, which is intended to strengthen the environmental alliance. As at the Teufelsbrück site, intensive advertising of the app is also required in Schnackenburgallee. Beyond the individual resident companies, this can be carried out bundled via a responsible mobility manager of the area.

Numerous employees from neighboring municipalities and districts who commute to Schnackenburgallee must also be considered in this study area. Here, the app could reach its limits due to the different tariff zones and transport associations.

S3 Mobilitäty hub/hvv switch-Punkt

Hamburg generally has an existing network of mobility stations (hvv switch points). Nevertheless, there is a need to create additional stations at essential locations (local supply centers, commercial areas) even away from more densely populated areas to strengthen the environmental alliance. Furthermore, the aim is to qualify mobility stations away from hvv switch by bundling various offers (public transport transfer, StadtRAD, bicycle parking facilities), even if they do not have the full extent of the hvv switch offer. The character of mobility stations also includes service facilities for testing new forms of mobility.

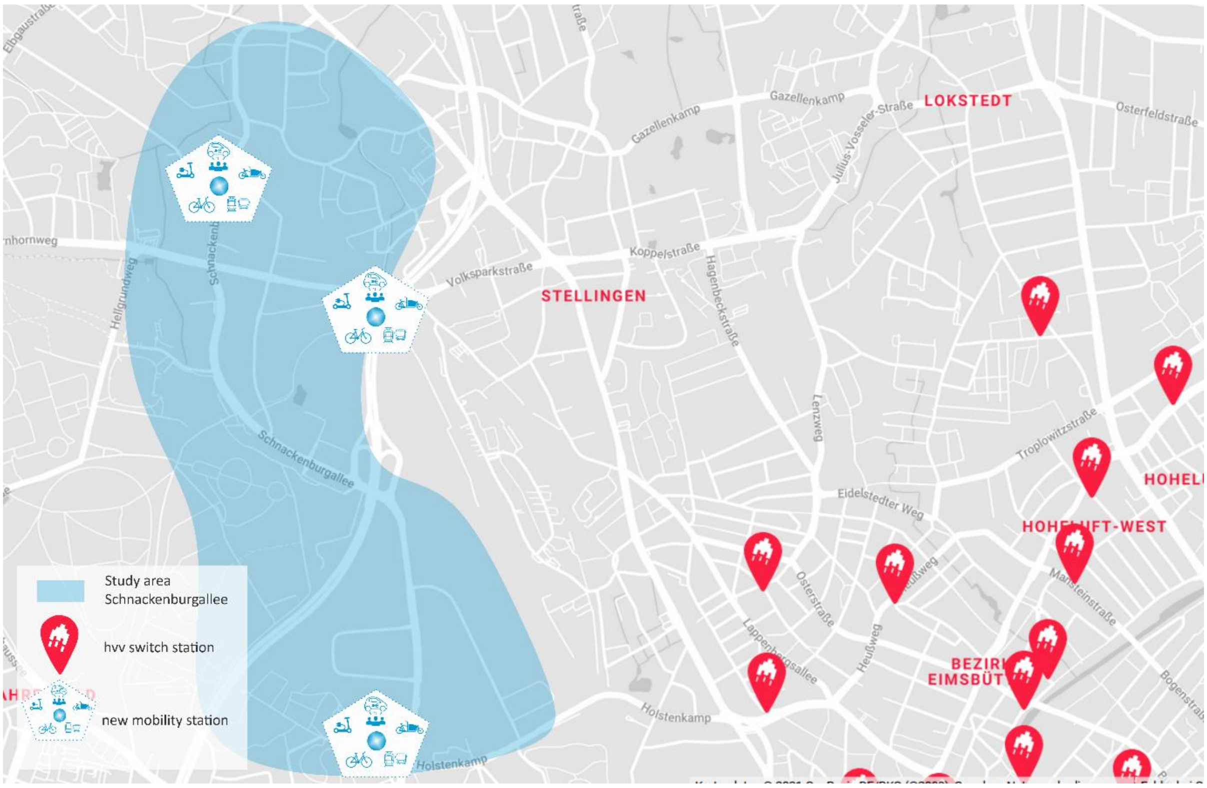

Figure 20: Location hvv switch points (source: own illustration, Planersocietät after hvv-switch.de)

In the Schnackenburgallee study area, the expansion of mobility stations should be centrally located, possibly depending on the subway expansion. A local area-wide StadtRAD network can be created by the new station at the stadium and development to all S-Bahn stops in the surrounding area and a central station in Schnackenburgallee. In particular, mobility stations are set up in the future at the Eidelstedt, and Stellingen S-Bahn stops directly adjacent to Schnackenburgallee. The system will be integrated into the Schnackenburgallee app so that the StadtRAD represents an independent and practicable mobility alternative in the study area. In addition, a feasibility study on micro-user hubs at the mobility stations is required so that additional routes of delivery traffic are also bundled in the commercial area by this means, and it leads to an overall reduction of this. For the suitable placement and dimensioning of the micro-user hubs, the demand and the delivery volume of the resident companies and the choice of means of transport of the employees must be taken into account[28].

A1 Autonomer e-Shuttle-Bus

In addition to the general expansion of the bus route network in the form of new or adapted routes, there is a high potential for new bus products. Neighborhood buses are conceivable here, which could be implemented in Schnackenburgallee as autonomous e-shuttle buses that operate across different companies. Similar to the HEAT model project, the fully autonomous e-shuttle bus will follow a fixed route, conceivably between the two S-Bahn stations Diebsteich and Eidelstedt. Here, the frequency can be adapted in particular to the usual working hours on weekdays, so that as many employees as possible can benefit from the new service. In the event of increased demand outside peak times, the e-shuttle bus can be requested via the app. The prerequisite for this is that the road infrastructure of Schnackenburgallee meets the requirements for automated or autonomous vehicles.

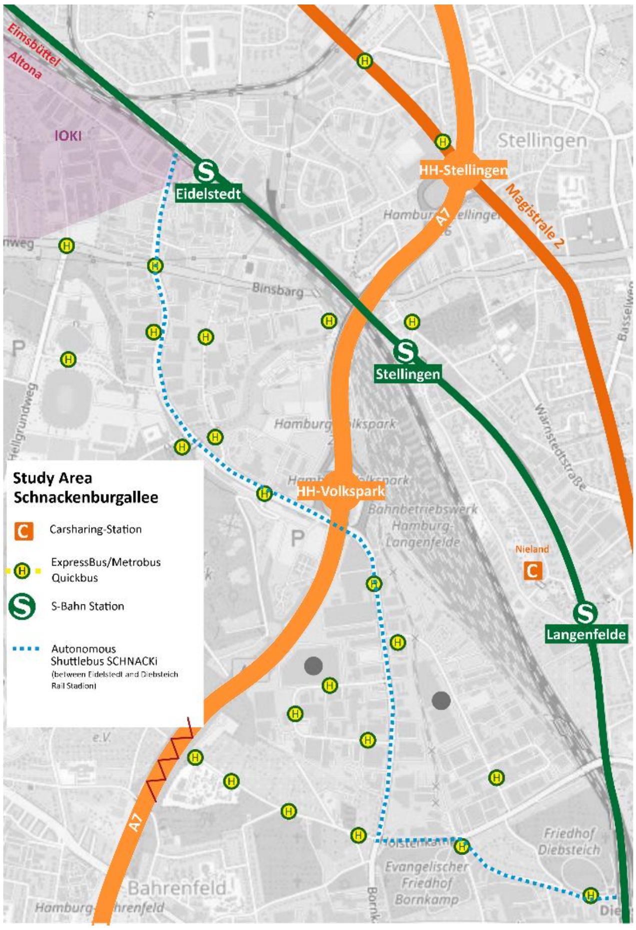

Figure 21: Shuttlebus Schnackenburgallee

V1 Priority for cyclists

In an urban traffic system, traffic can be controlled in a targeted manner. In particular, cyclists and buses can be given priority at intersections. To ensure that many people will use bicycles to get to work in the future, the necessary infrastructure must be provided on the one hand, and on the other hand, they must feel an advantage over car users. Copenhagen can be seen as examples of this. Here, cyclists are given a green wave in road traffic at a constant speed of 20 km/h. LEDs integrated into the asphalt signal the ideal speed. In addition to a fixed traffic light circuit, the system will in the

[28] For further results see report Feasibility Study - Logistics Hub Altona within the HUPMOBILE project.

future use sensors in the bike lane to detect groups of cyclists approaching intersections. If the sensors detect more than five cyclists, the traffic light phase will remain green for longer. In addition, illuminated signs can indicate when the next green traffic light phase will occur. A similar approach is already being tested in Hamburg through the PrioBike-HH pilot project.

V2 Priority for PT

The ITS project Bidirectional Multimodal Networking (BiDiMoVe), which is already underway in Hamburg, aims to give buses priority over other road users at traffic signals depending on the situation. The system will also test a turn assistant that warns bus drivers of crossing cyclists and pedestrians. The information gained from the pilot project can be transferred to Schnackenburgallee. This would make bus travel more attractive and increase the safety of cyclists and pedestrians.

B1 Pedestrians

A dense network of footpaths is the basis for short distances. Anchor points of pedestrian traffic, residential areas, workplaces, infrastructures, and leisure/tourism destinations are connected via direct and attractive routes. In order to ensure a continuous network of footpaths, it is necessary to close gaps in the network or open up further connection possibilities since people on foot are susceptible to detours due to their low speed of movement. This is especially true for people with limited mobility. Furthermore, the crossings and intersections at the junctions along Schnackenburgallee must be made pedestrian-friendly. Here, the need for crossing must be identified and made possible in a simple, safe, and barrier-free manner to reduce separation effects[29].

B2 Cycle traffic

The entire bike path infrastructure must also be massively expanded, qualified, and modernized on Schnackenburgallee. A safe and attractive cycling network is an essential prerequisite for the regular use of bicycles as a means of everyday transport. In addition, infrastructural network expansion should be prioritized based on the defined cycling routes. In doing so, it is vital to consider the different target and age groups as well as the purpose of the trip. In addition to the network concept, a consistently good, resilient, and safe infrastructure is required to do justice to the holistic promotion of cycling. For example, the increasing variety of models (cargo bikes, pedelecs, recumbent bikes, etc.) also places growing demands on a functional cycling infrastructure (e.g., safety, width, surface condition, maintenance).

[29] Further contents are contained in the climate protection subconcept Mobility in Altona and the climate protection subconcept Commercial.

In the Schnackenburgallee study area, existing network gaps must first be closed. This is primarily the case in the southern part (Binsbarg), former railway tracks, and Volkspark. The bicycle routes south of Schnackenburgallee must be integrated into an overall network of bicycle infrastructure. In perspective, the Hamburger Deckel in Othmarschen/Bahrenfeld must be included in the bicycle route planning between Schnackenburgallee and the southern part of Altona.

B3 PT

With the Hamburg-Takt, it should be possible to reach a public mobility service in less than five minutes by 2030. In addition to establishing new forms of mobility, the existing ones must be further expanded. This applies to public transportation, which currently does not provide sufficient access to Schnackenburgallee, primarily because the frequency is too low and there is no coordination with other bus and S-Bahn lines. In particular, the reinforcement of lines 22 and 180 has a high priority for better development of the study area. The improvement of the bus service in the area of Schnackenburgallee is thus carried out in a tighter frequency, which should also be maintained in off-peak times.

5. Summary and transferability to other cities

Traffic and mobility are experiencing dynamic growth in the Hamburg metropolitan region. This increase leads permanently to numerous problems: Impairment of the quality of life, higher accident rates, excess usage, traffic bottlenecks, competition for (free) space in public areas, traffic jams, and harmful environmental impacts are the result. This is where digitization in transport - Intelligent Transport System - can act as a game-changer, as it can counter the challenges mentioned above. On the one hand, ITS systems' targeted and planned use intelligently manages traffic and guides it through the city, resulting in fewer harmful environmental impacts. On the other hand, the service offers completely new forms of mobility so that inter-and multimodality becomes seamless mobility in everyday life in Hamburg.

The claim of the Hanseatic city to take a pioneering role in the development of ITS systems was communicated early on through the adoption of the ITS strategy in 2016. Mainly through its role as host of the ITS World Congress in 2021, it is evident that Hamburg intends to represent this role far beyond Germany.

In developing the individual measures in the study areas, the focus was on the fields of action of the ITS strategy, and it was considered that each field is taken into account or at least touched upon. The numerous projects already implemented in the Hanseatic city also serve as a template. Examples of best practices include the autonomous HEAT bus, the inter-and multimodal mobility app switch linked to the numerous hvv switch points, the on-demand shuttles IOKI and MOIA, and the PrioBike-HH.

Teufelsbrück, Mitte Altonas, and Schnackenburgallee turned out to be the study areas in the ITS potential analysis. The selection was made deliberately because three different areas (a commercial area, an innovative urban mixed-use neighborhood, and a traffic bottleneck) can be mapped, all of which can be found in large cities (as well as in port cities) and all of which have different mobility needs and requirements. This ensures transferability to other cities with similar spatial typologies.

In the ITS potential analysis, Teufelsbrück represents the congested traffic bottleneck on weekdays during regular working hours. Here, traffic is generated on the way to work and again on the way home. ITS-supported measures must address how the route is taken and relieve the bottleneck with innovative digital solutions. At Teufels-brück, the transfer to the ferry represents a unique situation for port cities. In Hamburg, most people take the bus or their car to get to the ferry. By installing a mobility station (hvv switch point) in conjunction with the mobility app and an additional mobility screen, employees are encouraged to switch to mobility alternatives. These consist of sharing offers (bike, ride, car), whereby active mobility should be prioritized, as this is the only way to reduce the total amount of traffic pollution. Thus, the local offer must be so attractive that the users switch to active forms of mobility.

For the urban mixed-use neighborhood, it can be stated that there is a surplus of uses here and that mobility and traffic are explicitly triggered by leisure trips in addition to everyday trips to work. Furthermore, different services (traffic, deliveries, stay, play) compete for the limited available space in public areas. Consequently, ITS measures have to be applied in different ways. In addition to the installation of hvv switch points in the neighborhoods in conjunction with the use of the mobility app, the focus is mainly on dealing with the growing CEP service providers due to the increasing volume of deliveries. The hvv switch point, in contrast to the traffic bottleneck, must particularly address the everyday needs of the residents. These include leisure activities as well as routes to work or the local supplier. Thus, the installation requires an exact pre-analysis of the needs of future users.

A business park is characterized by delivery traffic (B2B) and the work routes of the employees. ITS-supported measures must be implemented at these two points. Delivery traffic must be smartly routed through the area. As a basis for subsequent ITS measures that are intended to change the mode choice for commuting to work, the required infrastructure for safe bicycle and pedestrian traffic must be in place. If this is ensured, ITS systems can be used to influence the employees' choice of transport to work. Since the number of employees and company structures of the companies located in an industrial park are known, an autonomously operating shuttle bus can be deployed at peak times. Mobility stations can also have a targeted influence on a modal shift.

Finally, the potential analysis in Hamburg shows which ITS-supported fields of action and measures can be considered for different spatial typologies. The selection of the individual study areas ensures transferability to the HUPMOBILE partner cities Tallinn, Turku, Riga, and Helsinki. The basis for future-oriented digital mobility is an ITS strategy implemented in the municipality, which defines the goals, fields of action, and measures. These must then be transferred to individual pilot and focus areas.

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