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Making Hamburg a cycling city through Smart Velomobility

An investigative research on how Hamburg can use Smart Velomobility to achieve their mobility transition objectives

Colophon

M.Sc. thesis

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Image on the front page shows the Ballindamm in Hamburg.

Abstract

Research has shown that Smart Velomobility (SV) is usually underrepresented in ITS policy documents from the European Commission. However, little is known about the integration of SV in ITS strategies of individual cities. Additionally, the mobility transition is a frequently discussed affair in the political and scientific discourse. In Hamburg (Germany), the objectives of the ITS strategy and of the mobility transition partly overlap. Therefore, this thesis investigates to what extent SV can contribute to Hamburg's mobility transition and which SV measures should preferably be implemented in the context of Hamburg.

By analysing 42 ITS Hamburg projects in-depth and conduct five expert interviews, this knowledge gap is addressed for the case of ITS Hamburg. Results show that SV is considered in Hamburg's ITS strategy and that it can be used as a tool to bring about the mobility transition. SV is, however, not an alternative for physical bicycle infrastructure. Nevertheless, SV is still less discussed in Hamburg's ITS strategy than more dominant modes of transport. The SV Index developed as a result of this research can be used as a tool for City Planners and Politicians to measure a cities' SV. Additionally, advise is given on what SV measures should be focused on in the context of Hamburg. Further research is needed to examine whether a fixed budget can be assigned to SV, and what types of SV projects are demanded by different cyclists.

Key words: Smart Velomobility, Smart City, IoT, Smart Mobility, Intelligent Transportation Systems, Hamburg, Case-Study, qualitative and quantitative research methods, Mobility Transition, Cycling, Policy Advise

Colophon

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List of abbreviations

ADFC	Allgemeiner Deutscher Fahrrad-Club (The General German Cyclist‘ Union)
aVME	Automatisierte Verkehrsmengenerfassung (Automated Traffic Volume Detection)
BiDiMoVe	Bidirektionale, Multimodale Vernetzung (Bidirectional, Multimodal Connecting)
BITS	Bicycle and Intelligent Transport Systems
BMVI	Behörde für Wirtschaft, Verkehr und Innovation (Authority for Economy, Traffic, and Innovation)
BVM	Behörde für Verkehr und Mobilitätswende (Authority for Traffic and Mobility Transition)
CDO	Chief Digital Officer
CROW	Centrum voor Regelgeving en Onderzoek in de Grond-, Water- en Wegenbouw en de Verkeerstechniek (Dutch authority that gives guidelines for traffic road authorities)
EC	European Commission
ECB	European Central Bank
EEA	European Environmental Agency
EU	European Union
GDR	German Democratic Republic
HaRaZän	Hamburger Radverkehrszählnetz (Hamburg bicycle counting system)
HEAT	Hamburg Electric Autonomous Transportation
HGV	Heavy Goods Vehicle
HVV	Hamburger Verkehrsverbund (Hamburg’s Transport Network)
IoT	Internet of Things
ITS	Intelligent Transport Systems
MaaS	Mobility as a Service

MRQ	Main research question
MT	Mobility Transition
PM2.5	Fine particulate matter
PMO	Project Management Office
SRW	Sub research question
SUMP	Sustainable Urban Mobility Plan
SV	Smart Velomobility
TAVF	Teststrecke für automatisiertes und vernetztes Fahren (Test track for autonomous and connected driving)
TIMS	Traffic Information Management System
TIQ	Testfeld Intelligent Quartiersmobilität (Test field intelligent neighbourhood mobility)
TLF	Traffic Light Forecast
USA	United States of America
WHO	World Health Organisation

1. Introduction

1.1. Relevance

Cities around the world are struggling to meet emission targets. In Europe, almost 25 per cent of the greenhouse gas emissions result from transportation. While other sources of emission like agriculture and industry decreased in the last decades, transportation emissions only started to decline in 2007 and are still higher than in 1990 (European Union, n.d.). According to EEA, Hamburg ranks 125th out of over 300 cities in EEA member countries. In 2019 and 2020, the EEA measured an annual average of 9 µg/m3 of PM2.5 in Hamburg, just below the WHO annual guideline value for a good level of fine particulate matter (European Environment Agency, 2021; WHO, 2018).

Even though the air quality seems to be sufficient in Hamburg, the city still struggles to meet the limit values on some highly frequented streets. The city assigned driving bans on two road stretches for older diesel cars and HGVs that do not follow the Euro 6 emission standard to reduce emissions. Hamburg might be obliged by the supreme administrative court of Germany to introduce new driving bans in the future (NDR, 2021).

For years, transport planners primarily saw cycling as a hobby instead of a legitimate mode of transport. In traffic planning, the bicycle has often been marginalised (Koglin & Rye, 2014). However, in recent years there is a growing network of planners, advocates and researchers that actively promote bicycle infrastructure planning (Pucher & Buehler, 2017). The pressure on cities to reduce the negative impacts of urban traffic is growing. Both cycling (Fishman, 2016) and the smartification of mobility are seen as solutions to mitigate the negative effects of urban traffic (Behrendt, 2016; Koglin & Rye, 2014; Nikolaeva et al., 2019).

It may sound logical to combine Smart City initiatives and bicycle infrastructure improvements. However, Smart City and ITS on the local, national and global levels usually do not consider Smart Velomobility. Behrendt (2016) defines it as follows: *"Smart Velomobility […] is concerned with networked practices, systems and technologies of cycling."* (Behrendt 2016, p. 157).

The effects of autonomous vehicles on cycling are unclear. Autonomous vehicles will likely improve the convenience of driving by (autonomous) cars since 'drivers' will not have to worry about finding a parking spot (Thomopoulos & Givoni, 2015). Autonomous cars also can increase bicycle usage (Latham & Nattrass, 2019; Pettigrew et al., 2020) but may also make cycling more dangerous in the transition phase towards autonomous traffic (Botello et al., 2019). Solutions should be found to keep cycling a competitive mode of transport to prevent harmful effects caused by more (autonomous) vehicles on the road (Koglin & Rye, 2014).

Bicycle boom

The outbreak of the COVID-19 pandemic resulted in a boom in cycling in many cities. Within Germany, the number of people that claimed to use a bicycle daily rose from 17 to 22 per cent in 2020 compared to 2019 (Follmer & Gruschwitz, 2017). Sharifi et al. (2020) also showed that cities with a high modal share of cycling are more resilient to the COVID-19 pandemic; social distancing is easier on a bike than in public transport, and bicycles take less space than private cars (Sharifi & Khavarian-Garmsir, 2020). Also Doucet & Mazunder (2020) stress that providing cycling infrastructure can be part of building a more equitable city because it is more accessible and affordable than most other modes of transport.

However, besides a (future) pandemic, cycling has many benefits. The benefits of cycling are that cyclists hardly cause any environmental damage, it improves cyclists' health through moderate exercise. Furthermore, cycling is an efficient mode of transportation that is also suitable for longer

distances than walking (Pucher & Buehler, 2008, 2017). Cycling is also a highly economical mode of transport for the cyclist itself and society. According to the Dutch Cycling Embassy, a kilometre travelled by bike has a social benefit of 0.68 €, whereas cars and busses cost the society respectively 0.37 € and 0.29 € per kilometre (The Dutch Cycling Embassy, n.d.).

In short promotion of cycling pays back because cycling is economical, leads to more resilient and equitable cities and is an excellent tool to reduce the environmental impact of urban transport. The City of Hamburg acknowledges these benefits of cycling (Hansestadt Hamburg, 2018a).

Bitkom

Bitkom ranked Hamburg as the smartest Smart City of all German cities above 100,000 inhabitants in 2020. The city scored the most points in the general Smart City ranking in which the cities are compared for 136 parameters in five topic areas (city administration, IT and communication, energy and environment, mobility, and society). Hamburg scored 96.77 points in the category mobility, followed by Munich (91.04) and Aachen (83.75). The city was honoured for its variety of modes of transport that can be used and paid for with the HVV Switch app (MaaS) (Behesthi-Kashi et al., 2020; Bitkom, 2021).

1.2. ITS Hamburg strategy

In April 2016, the senate of Hamburg passed the ITS strategy. With this strategy, the city wants to use the opportunities of information and technology to shape the urban mobility of the future. The mobility of the future should be more efficient, comfortable, and sustainable. To reach the ITS strategy objectives, the individual projects are divided into six fields of action (see chapter 2.2.3.) (Hansestadt Hamburg, 2016, 2018b).

For the different fields of action, the city developed an interim goal for 2021 and a goal for the year 2030. The partial strategies together form the ITS Hamburg strategy. Individual projects can be part of overlapping fields of action. Following ITS objectives are used to judge the effectiveness of the projects.

- Increase traffic safety;
- Reduce traffic-related environmental impact;
- Increase the reliability and efficiency of the transport network;
- Good and safe distribution of information;
- Stimulate innovation (Hansestadt Hamburg, 2016, 2018b).

All these objectives have the potential to benefit cycling.

ITS Hamburg Congress

Part of the Hamburg ITS Strategy is the ITS World Congress. In 2017 Hamburg received the approval to organise the ITS World Congress in October 2021. With the congress, the city wants to show the worldwide visitors how they achieved to make the urban traffic system efficient and sustainable. At the congress, visitors are informed about the preliminary projects already completed and the further projects that are planned until 2030 (Hansestadt Hamburg, 2018b).

National German bike conference

Hamburg also hosted the national bike conference in April 2021. At this congress, experts and visitors discussed topics like planning better bicycle infrastructure through data and the opportunities of MaaS. Also, among others, the Hamburg bicycle counting system (HaRaZän) project was introduced and debated on the congress (Hansestadt Hamburg, 2021a).

1.3. Mobility transition in Hamburg

Together with the ITS Strategy, Hamburg wants to push the mobility transition. In the coalitions agreement, 2020-2025, between SPD (Labour Party) and die Grüne (the Green Party), the parties set the goal to increase the modal split from 22 per cent in 2017 to 30 per cent in 2030. Also, the trips taken by bicycle should increase to at least 25 per cent by 2030 (Hansestadt Hamburg, 2020).

Hamburg aims to improve or build at least 50 kilometres of bicycle infrastructure annually (Hansestadt Hamburg, 2018a). Furthermore, public transport should be significantly improved. More metro's and trains should ride in 2030, and through new bus lines and one demand services, everyone in Hamburg should reach a form of public transport within five minutes (Hansestadt Hamburg, 2019c).

However, how can Hamburg accelerate the process of the wanted mobility transition? And how can this be integrated into the Smart City strategy of Hamburg?

1.4. Research gap

Behrendt (2019) researched the political discourse of Smart Velomobility compared to other modes of transport in Smart City and IoT policy documents of the European Commission. However, not much is known about this relationship in the context of an individual city. Also, the contribution of Smart Velomobility to the mobility transition is not extensively researched. Therefore, this thesis investigated the case of the Hanseatic City of Hamburg.

1.5. Research questions

1.5.1. Main research question

The mobility transition objectives and ITS strategy from the city of Hamburg are two strategies that were developed in a different political climate. They, however, show some overlapping objectives (table 1), which brings us to the main research question below.

MRQ. To what extent can Smart Velomobility contribute to Hamburg's wanted traffic transition?

Mobility Transition objectives (Hansestadt Hamburg, 2019b; Tjarks, n.d.)	ITS Strategy objectives (Hansestadt Hamburg, 2016, 2018a)
Safer urban traffic	Increase traffic safety
Reduce traffic-related environmental impact	Reduce traffic-related environmental impact
More comfortable and more convenient urban mobility	Increase the reliability and efficiency of the transport network
Better provision of information	Good and safe distribution of information

Table 1 Comparison of the mobility transition- and ITS strategy objectives from the City of Hamburg

1.5.2. Sub research questions

Several sub research questions help with answering the main research question. This research elaborates on how the city of Hamburg can implement Smart Velomobility in its ITS strategy. It aims to find out how smart technologies can help improve conditions for cycling in the city of Hamburg.

The first sub research question that will be answered is *SRQ1. To what extent is Smart Velomobility considered in Hamburg's ITS strategy?* As described before, Smart Velomobility is not considered much compared to other modes of transport in Smart City and IoT policy document of the European Commission (Behrendt, 2019). This research answers whether this is also the case in Hamburg's Smart City strategy.

The second sub research question is *SRQ2. How are the priorities in the ITS measures of Hamburg decided? How do different powers relate?* Traffic planning is a highly controversial and political topic. Cyclists have often been marginalised in traffic planning (Koglin & Rye, 2014). This research answers how the priorities are defined and how ITS projects come into play.

Smart Velomobility offers many opportunities to make cycling more attractive (Behrendt, 2016, 2019, 2020; Botello et al., 2019; Interreg North Sea Region, n.d.; Popan, 2019). However, not every context is the same and therefore, the type of Smart Velomobility projects should fit the local context. *SRQ3. What are the opportunities for Smart Velomobility in Hamburg? Which Smart Velomobility measures should be taken in Hamburg? For which target groups?*

Smart Velomobility measures may also have disadvantages like potential privacy violations (Behrendt, 2016; Streitz, 2019) or the exclusion of certain groups (Baltac, 2019; Mclaren & Agyeman, 2018). For sub-question four, it is critically reflected upon the potential disadvantages of Smart Velomobility in Hamburg. SRQ4. What are the disadvantages of Smart Velomobility in Hamburg?

1.6. Thesis structure

The remainder of this thesis is structured as follows. Chapter 2 provides a theoretical framework about Smart City, ITS and Smart Velomobility. Further on, the specific context of Hamburg is discussed, and a conceptual framework with the relations between the key topics is presented. In chapter 3 it is elaborated upon the methodology. Chapter 4 presents the outcomes of the policy analysis and expert interviews. In chapter 5, the research questions are answered. The thesis concludes with a reflection on the thesis process and recommendations for further research in chapter 6. The general interview guide can be found in the appendix.

2. Theoretical Framework

2.1. Smart City

Definition

The concept of a Smart City is broad. Different definitions exist and instead of what someone may think, Smart City is not a new concept. Smart City and other related terms were established in the early 1990s, as the internet became more dominant in society. Other terms used are ‘digital city’, ‘ubiquitous city’, ‘cyber city’, and ‘virtual city’ (Willis & Aurigi, 2017). This research uses the generic term Smart City.

Robert Hollands defines Smart City as follows:

> *"Effectively, a Smart City is made up of IT devices, industry and business, governance and urban service, neighbourhoods, housing and people, education, buildings, lifestyle, transport and the environment. [...] the unspoken assumption [...] suggests that the application of IT in cities will automatically benefit everyone, with prosperity and wealth being shared by all.” (Hollands, 2015, p. 64).*

As can be seen, this definition of Hollands (2015) is a somewhat optimistic perspective on the Smart City. However, some authors suggest that smart cities will not benefit everyone. Behrendt (2016, 2019, 2020) and Nikolaeva et al. (2019) indicate that the bicycle is underrepresented in Smart City discourses compared to other modes of transport like the car. Other scholars (McLaren & Agyeman, 2019; Lefevre, 2014; Baltac, 2019) worry about excluding certain groups. In chapter 2.1.2., it will be elaborated more on the potential downsides of the Smart City.

Smart City as a tool for urban planners

Shen et al. (2018) focus with their definition mainly on the role of the Smart City for the decision-makers. They do not mention how a Smart City can directly benefit citizens.

"The core of the concept of the Smart City is helping those decision makers to make intelligent and effective city-related decisions through offering them the adequate information at [the] appropriate time and accurate place with the help of all sorts of intelligent devices." (Shen et al., 2018, p. 2).

Many cities see the concept of Smart City as the solution for many urban problems like crime, traffic congestion, inefficient services, and economic prosperity (Hollands, 2015). The concept is perceived as an essential strategy to use technology to improve the urban environmental quality and make city services more efficient for its citizens (Benevolo et al., 2016).

2.1.1. Intelligent Transport Systems

Definition

Intelligent Transport Systems is defined as follows:

""Intelligent transport", or Intelligent Transport Systems (ITS) concerns the use of networked technologies for transport." (Behrendt, 2016, p. 158).

Smart urban mobility or ITS is a key element of the Smart City. It entails innovations like autonomous driving and mobile data connectivity. The latter allows for new integrated mobility services like ride-hailing and vehicle sharing to form an integrated mobility system. An integrated mobility system that allows easy transfer between mobility options goes by MaaS (Hansestadt Hamburg, 2018b). In recent years particularly lightweight so-called micro-mobility vehicles conquered market share in cities around the world. Micro-mobility vehicles are electric scooters, electric skateboards and (electric) shared bicycles (Frosio, 2020).

Benevolo et al. (2016) distinguish between three paradigms for a successful smart mobility system. The digital city, the green city, and the knowledge city.

- Digital city: ICT solutions can be used for a variety of functions in a smart mobility city. It supports the optimisation of traffic flow, urban planning of new and existing transport infrastructure and can be used for citizen participation.
- Green city: A smart mobility system should also be green in terms of minimal pollution and with urban greenery since urban mobility is a significant cause of pollution.
- Knowledge city: a smart mobility system should also depend on the sharing of civic values and the smart behaviour of the citizens. Policy makers can come up with good ideas. However, when it does not result in smart behaviour of the citizens, it is not practical.

A poorly managed mobility system has a substantial impact on the quality of life in urban areas. Pollution, bad (slow, expensive, and crowded) public transport, and congestion are just a few of those adverse effects (Benevolo et al., 2016). They distinguish the six most vital objectives of ITS. These objectives partly overlap with the objectives of ITS Hamburg, as stated in the introduction.

"1. reducing pollution; 2. reducing traffic congestion; 3. increasing people safety; 4. reducing noise pollution; 5. improving transfer speed; 6. reducing transfer costs." (Benevolo et al., 2016, p. 15).

2.1.2. Smart City debate

What Smart City will mean for the future of (urban) transportation is unforeseeable. Some scholars expect that Smart City and smart mobility will reduce the city's environmental footprint and the citizens' quality of life (Benevolo et al., 2016). Popan (2019), however, sketches a critical future of smart automobility. He claims that smart automobility will not benefit urban mobilities. The

realisation of the high tech future will be hampered due to the high cost of cars and the needed infrastructure and road congestion because cars still take up a considerable amount of urban space compared to other modes of transport, as illustrated in figure 1) (Grescoe, 2018). As explained in chapter 1, cyclists' minimum usage of spaces is also beneficial in pandemic circumstances like the current COVID-19-pandemic (Koglin & Rye, 2014; Sharifi & Khavarian-Garmsir, 2020).

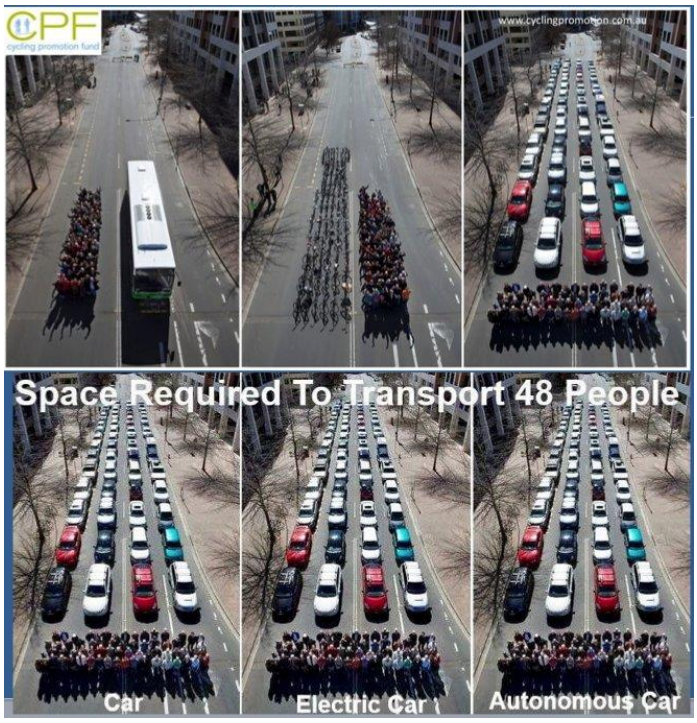

Figure 1 Space required to transport 48 people (Grescoe, 2018 & Cycling Promotion Fund, n.d.).

Is smart also sustainable?

Also, in terms of sustainability, the electric (autonomous) car cannot solve everything. In observations of around 4,000 people living in different European cities over two years, Brand et al. (2021) estimated that people who cycled daily had an 84 per cent lower carbon footprint for their daily travel than those who did not cycle regularly. Although the emissions of an electric car are already much lower than that of a car with an internal combustion engine, the researcher found that the carbon emission generated from cycling is around ten times lower than from driving an electric car (Brand et al., 2021).

Privacy

In the EU, privacy is seen as a crucial element for democracy. Due to the data gathering practices in Nazi Germany and the former GDR, Germans particularly value privacy and data protection high (Petkova, 2019). This high German valuation of privacy can also be observed in Germany's high rates of cash use. According to a study by the ECB in 2017, German consumers carry the most cash of all Euro area countries (103€). They carry considerably more than French (32€) and Dutch (44€) people (Esselink & Hernandez, 2017; Schütz, 2019).

Smart City applications may result in a digital exclusion or fears of privacy violation (Behrendt, 2016). When executing Smart City projects, there is a tricky trade-off between smartness vs privacy. On the one hand, privacy is a great good, but a certain level of data collection and processing is needed for many smart projects. Data gathering should always be transparent to keep these elements in control and ensure privacy, especially when external companies are involved. End-users should always make the decision themselves about what happens with their data (Streitz, 2019).

To ensure privacy a 'privacy by design' approach should be taken. *"[This] approach demands to make 'privacy' a first-order objective of system design and engineering and to embed it throughout the entire life cycle of technology development."* (Streitz, 2019, p. 800). The privacy by design principle must be backed up by legislation. In Germany, this legislation states that personal data belongs to the citizens and cannot be used without their consent (Streitz, 2019).

Exclusion

An ideal Smart City considers the needs, fears, and wishes of every citizen. Smart City is not something from which only the urban elite or business should profit. It should be prevented that the Smart City causes a new division between a city's population as other characteristics like age, income and race did (Mclaren & Agyeman, 2018). Lefevre (2014) worries that smart cities are mainly seen as opportunities for businesses to earn money. He suggests staying in a constructive dialogue between commercial partners, the city council, and the citizens. The city council must be a strong partner to ensure that only solutions are implemented that are the best for its citizens.

Another issue that needs be considered when planning smart cities is the digital divide. The digital divide is the gap between people who can easily access digital and information technology and those who struggle to access it. Not every citizen is a digital native or has the resources to use digital instruments. Especially the elderly non-digital native generation, and population groups with a low social economic status are affected by this digital divide (Baltac, 2019). He defines four pillars that should bridge the digital divide. The first pillar is appropriate IT infrastructure. The benchmark for a Smart City should not be the number of devices but the degree to which the population has access. Secondly, the internet should be accessible and affordable. Thirdly, the Smart City population should have the ability to use IT. Learning programs can help non-digital natives to get access to the information society and thus the Smart City. The fourth and last pillar is the availability of helpful content. A good Smart City application has up-to-date information, is available to a variety of devices (e.g. Android, IOS and older smartphones) and ideally offers multiple languages in a touristic or international city like Hamburg. A Smart City can successfully overcome this digital divide through the four pillars of Baltac (2019).

The final form of exclusion brings us to the main topic of this thesis: Smart Velomobility. Cyclists should not be excluded or marginalised physically and politically from ITS or Smart City projects (Behrendt, 2016; Koglin & Rye, 2014; Nikolaeva et al., 2019). The following chapter elaborates more on this topic.

2.1.3. Future of cycling

Smart Velomobility

Cycling can also profit from Smart City initiatives. Such Smart City tools related to cycling are called Smart Velomobility (see chapter 1.1. for a definition of Smart Velomobility). Even though the discourse is currently mainly about autonomous vehicles, new smart cycling technologies are gaining attention. This trend can potentially change the cycling experience and impact how cycling should be understood and governed (Nikoleava et al., 2019). Nikolaeva et al. (2019) analysed 86 website texts about Smart Velomobility applications. They outlined the potential changes in 'institutions, design regulations, and planning' and 'social interactions and embodied performances' as shown in table 2.

Aspect/ Level of change	Possible changes in institutions, design, regulations and planning	Possible changes in social interactions and embodied performances
Bicycle		Simplicity and connectedness
Relations between the bike and the cyclist	Facilitating cycling as a service	From owning to using a bicycle
Interactions between cyclists and social environments	Creating conditions for data sharing and usage	Remaining in one's social bubble; new social interactions through technology
Relationship between cyclist and spatial environment	Interactive landscape to protect and empower cyclists	Cyclists adapt to polluted or unsafe environments; cyclists interact differently with new infrastructure
Experience and meaning of cycling	Infrastructure enabling non-stop cycling; increase fun through gamification	Cycling as target-driven performance (e.g. Strava)
Governing cycling	Cyclists are treated more like drivers 'automobilization of cycling'; infrastructure is based on data that is monitored	Cycling either accept or protest that cycling becomes complexer; cycling collect data by default
Cyclists' lifestyle and identities		Expressing one' style via mobility

Table 2 potential influence of Smart Velomobility on different elements of cycling on the institutional- and social level. Adapted from Nikolaeva et al. (2019).

Bicycle pyramid

The BITS project is a best practice example of using ITS to make cycling more attractive. It is a cooperation of serval regional governments, knowledge institutes and companies. BITS stands for bicycle and ITS and is supported by the North Sea Programme of the European Regional Development Fund of the European Union. Some regions participating in BITS already have a high bicycle use, like the Netherlands, Denmark, and Belgium. However, also partners from the upcoming bicycle nation Germany are participating. The Interreg project developed the bicycle pyramid below (Interreg North Sea Region, n.d.).

To determine which kind of Smart Velomobilty projects are needed in a particular environment, BITS developed the bicycle pyramid derived from Maslow's hierarchy of needs pyramid (figure 2). The elements at the bottom of the pyramid are the most important (safety & reliability). This means that these factors must be met before striving for elements higher up the pyramid (speed & convenience and comfort & experience). In other words: *"cycling can be made more attractive by improving the surrounding but improving the surrounding will not have a big impact if cycling is dangerous"* (Interreg North Sea Region, n.d.)

Simultaneously, the ITS applications on the different levels will generate data that can be stored in a CycleDataHub (Interreg North Sea Region, n.d.). In Hamburg, various data from different city departments is already publicly available on the Urban Data Platform. City employees, companies and citizens should profit from synergies and added value that open data brings (Hansestadt Hamburg, n.d.b).

The data from the CycleDataHub has several advantages that are also portrayed in the pyramid. Open data can be shared with different stakeholders like Hamburg is already striving for. Furthermore, data can be used to inform cyclists either through apps or via physical infrastructure

on the roadside. Lastly, bicycle data is an excellent input for city planners to improve their cycling policy (Interreg North Sea Region, n.d.). Chapter 4.1. answers on which level of the pyramid Smart Velomobility projects are conducted in Hamburg and what is done with bicycle data in Hamburg.

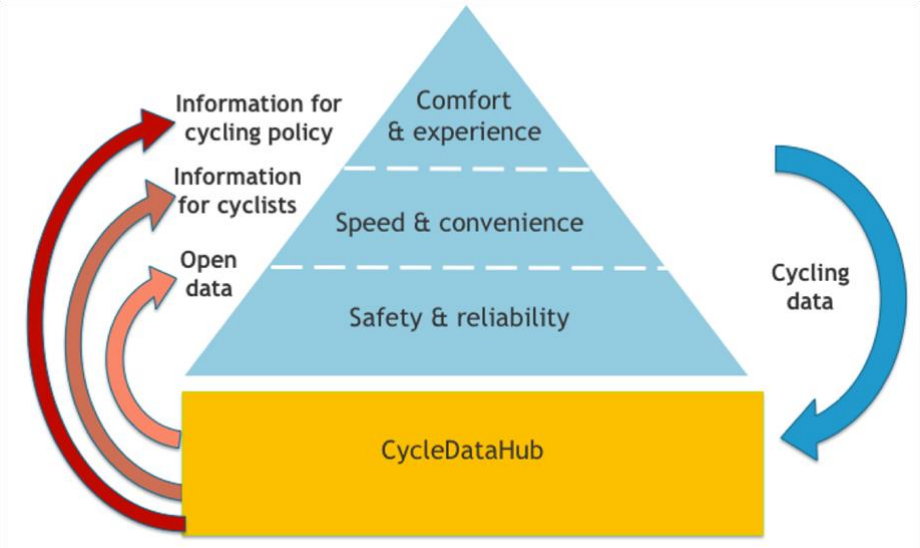

Figure 2 Bicycle and ITS Pyramid (Interreg North Sea Region, n.d.).

Data reflex

Every possible tool must be deployed to get more people cycling. Direct information gathering is currently the primary source for cycling data. However, through Smart Velomobility projects, new opportunities for data collection occur. This data can be of high value for urban planners. To use the opportunities of newly generated data Jorna & Kleine (2020) stress that urban planners should develop a data reflex. The data reflex starts by storing data and making it available to all stakeholders and entails four crucial elements (figure 3):

1. Data should be published in an open data hub;
2. People responsible for the data should also understand the data and what purposes the data may have;
3. Planners should make a concept on how the data should be processed. The data should be valuable while keeping privacy concerns in mind;
4. The last step is publishing the data. From this data planners can learn more about cyclists behaviour and new ITS concepts can be developed to benefit cyclists even more (Jorna & Kleine; Province of Antwerp, 2020).

Figure 3 Data-reflex (Province of Antwerp, 2020).

Data is often a by-product from ITS applications. For example, a smart lamp post that turns of when a cyclist is in sight could also use that tracking information to count the cyclist. Jorna & Kleine (2020) advise traffic planners that want to use a Smart Velomobility application to not only aim for the primary objectives of a project. Other applications, such as counting cyclists, may be possible when the data reflex from Soeters is applied. Data allows considering the behaviour and needs of cyclists better (Jorna & Kleine).

Marginalisation of cycling

Bent Flyvbjerg is an often-stated author when it comes to power, planning and transport. In his analysis of an infrastructure project in the City of Aalborg in Denmark, he shows that power relations are an essential factor to consider. With the term ‚imaginary rationality', he describes the phenomenon that the people who have the power to decide also create their imaginary version of reality. People who have power thus can influence politicians and shape how people transport themselves through the city. This gives urban planners the responsibility to carefully consider the powerless in transport planning (Flyvbjerg, 1998).

Behrendt (2016, 2019, 2020) and Nikolaeve et al. (2019) criticize that cycling is often not considered in Smart City debates, which results in a lack of funding opportunities. Proponents of autonomous vehicles claim that they will make streets more efficient, productive, and safe. However, the future will tell if that will be the case or whether they push out alternative forms of transportation as happened in forms of automobility (Latham & Nattrass, 2019). A similar effect could be observed in the National Socialism era in Germany. The seemingly bicycle-friendly policy of building separate bicycle paths was to keep the roads clear for motorised traffic. In the same era, the obligation of bicycle path usage was introduced (Briese, 1993).

According to Koglin & Rye (2014), there is a lack of empirical, theoretical research in bicycle planning, which is one reason for the marginalisation of cyclists in transport systems. Different characteristics like topography, urban density, mixed-use, culture, and climate influence the bicycle modal split. However, the most crucial factor is the extent to which cyclists are considered in urban planning. Planners should not only plan for the people that already cycle but should consider the needs for a wide range of cyclists (Koglin & Rye, 2014).

Different types of cyclists

In 2006, Geller defined four types of cyclists: 1. *The strong and fearless, 2. the enthused and confident, 3. the interested but concerned* and *4. the no way no how type*. They are distinguished by their willingness to ride on different types of bicycle infrastructure. *The strong and fearless type* would cycle in every circumstance even when there is no specific bicycle infrastructure. However, with under 1 per cent of all potential cyclists, this group is relatively small. The second group would also cycle in most circumstances but is more comfortable when offered bike lanes. This group makes up around 7 per cent, according to Geller. The third group is more reluctant and needs to be persuaded with good bicycle infrastructure. The group makes up 66 per cent of the population. Getting this group on the bike is what distinguishes bicycle cities from non-bicycle cities. The last group, consisting of 33 per cent of the people, feels uncomfortable on best-practice bicycle infrastructure or is physically unable to cycle. This group will not even cycle in the world's best bicycle cities (Dill & McNeil, 2013). However, a survey from the Wheels for Wellbeing showed that 69 per cent of disabled cyclists find cycling easier than walking. This suggests that the initial percentage of the *no way no how type*, might be lower than estimated by Geller in 2006 (Clement & Andrews, 2017).

After a Germany-wide survey among cyclists, Francke & Lissner (2021) distinguish between four types of cyclists (functional, passionate, pragmatic, and ambitious). Their study showed that cycling data based on GPS is a comparably cheap way of getting an overview of the behaviour of cyclists. It primarily allows for detailed knowledge. The functional cyclist shows the least intrinsic motivation

to cycle. This group mainly cycles for economic reasons, speed compared to other modes of transport, environmental protection, and flexibility. This group usually cycles in 'good' weather conditions and feels relatively unsafe in mixed traffic conditions compared to the other groups. Secondly, the passionate cyclist, cycles regularly and feels safe in most traffic conditions. Thirdly, the pragmatic cyclist cycles because his or her family and friends also do that. There are not confident on the bike and in traffic. And finally, the ambitious cyclist is a cyclist who likes to drive longer distances on the weekends but who does not cycle regularly. Smart Velomobility can bring more knowledge on where different cyclists like to ride and what can be done to serve them better (Francke & Lissner, 2021).

Also, in planning for Smart Velomobility, different types of cyclists with different levels of digital literacy exist. *"Digital literacy means having the skills you need to live, learn, and work in a society where communication and access to information are increasingly through digital technologies like internet platforms, social media, and mobile devices."* (Western Sydney University, n.d.). The four pillars of Baltac (2019) can be applied to reduce digital illiteracy (chapter 2.1.2.).

Future scenarios

Researchers from the Dutch Ministry of Infrastructure and the Environment (KiM) have developed four future scenarios on how the future of transport could look—ranging from less to more automation and with people sharing their vehicles more or less (figure 4). Towards which scenario the future of autonomous vehicles will move also determines the effects on sustainability and the use of other modes of transport like cycling. In the *fully automated private luxury* scenario, transport in autonomous vehicles becomes comparably convenient. Therefore, the number of kilometres driven will increase drastically and trips taken by bike will reduce in this scenario. The *Multimodal and shared automation* and *Mobility as a service: any time, any place,* are expected to affect the use of bicycles positively. Warning systems in cars and more intensive use of public transport result in increased road safety. Also, incorporating the bicycle in multi-modal trips becomes more accessible with Mobility as a Service (MaaS) applications (Tillema et al., 2015).

As explained in the introduction, autonomous cars may make cycling more dangerous or inconvenient (Botello et al., 2019). From a more positive outlook, autonomous vehicles could also be particularly cautious about the safety of non-motorised traffic over the demands of traffic efficiency. Compared to the current situation in which drivers consciously and unconsciously make mistakes, this future would benefit cyclists and potentially increase bicycle use (Latham & Nattrass, 2019; Pettigrew et al., 2020).

Toward which scenario the future urban traffic will move to is unforeseeable. Autonomous vehicles can have positive and negative effects on cycling. Urban planners should stay aware of their influence on urban cycling. The marginalisation of the bicycle as a mode of urban transport, as described by (Koglin & Rye, 2014), should be prevented by all means.

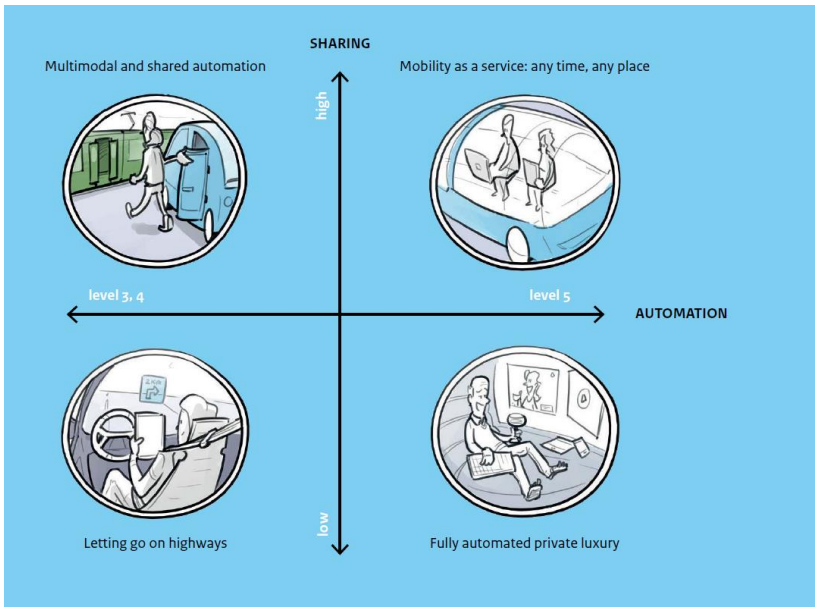

Figure 4 Four scenarios for future traffic and transport systems involving self-driving cars (Tillema et al. 2015).

2.2. Hamburg context

2.2.1. Hamburg state level

ITS Hamburg strategy program management

When the ITS Hamburg strategy was first decided, the BMVI was primarily responsible for the ITS Hamburg strategy. The connected CDO functioned as the central authority for all digitalisation activities in which the BMVI participated. As of 2020, the tasks of the BMVI were transferred to the new BVM. The CDO also moved to the new authority (figure 5) (Tjarks, n.d.; Hansestadt Hamburg, 2018b).

Coordinating the ITS Hamburg is a complex process; for this task, the ITS PMO was established. The PMO secures a successful realisation of the ITS projects. It links the variety of measures and stakeholders and deals with potential conflicts. Furthermore, the PMO organises meetings between stakeholders working for the ITS strategy. To monitor the projects, the PMO set up the PMO Dashboard. On this dashboard, all ITS Hamburg projects are visualised. The PMO is supported by the The Network Management Office and is the first contact person for external businesses and institutions that may want to cooperate. ITS Hamburg 2021 GmbH, on their behalf, takes care of all tasks related to the ITS World Congress 2021. Their assignment is to prepare the congress and coordinate with over 120 partners from the industry and science (Hansestadt Hamburg, 2018b).

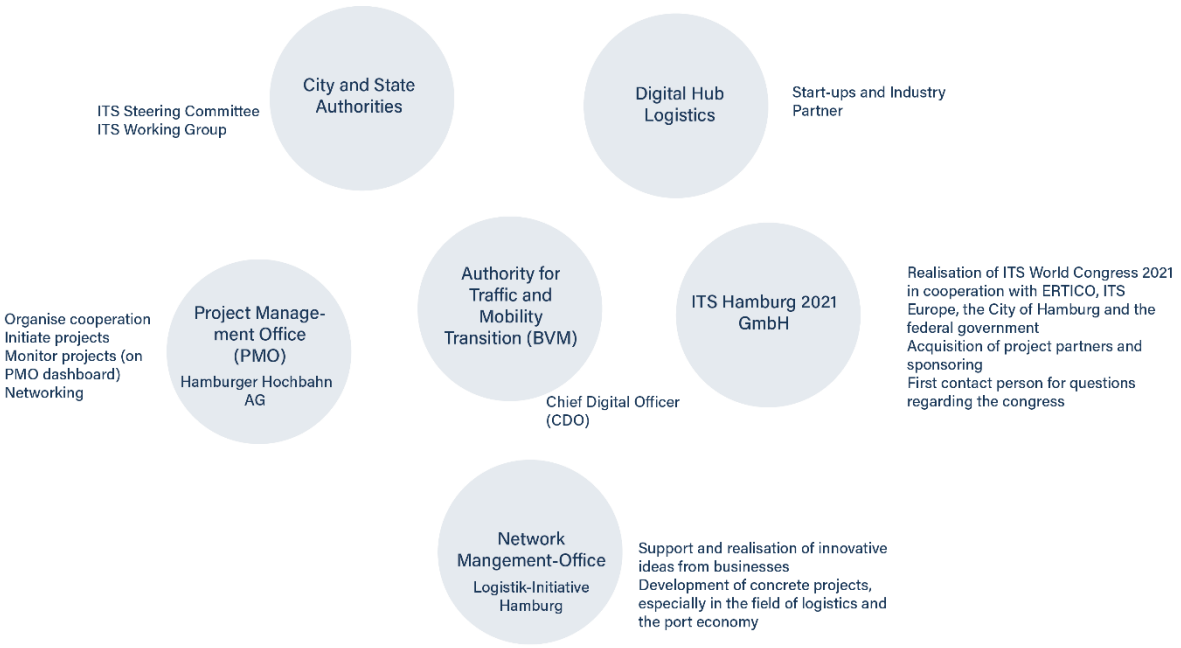

Figure 5 Stakeholder for ITS Hamburg. Adapted from (Hansestadt Hamburg, 2018b).

There are four groups part of the programme management (see figure 6). The first level is the ITS Steering Committee with the management level of the local government and organisations such as the ITS 2021 GmbH, universities, the airport and other organisations. The second level is the ITS Working Group. In this group, project leaders and experts from local governments and organisations are present. In the third group, there are two supervisors for each of the six fields of action to advise on how the strategic goals should be met. Additionally, the ITS Community has various companies, start-ups, and citizen participation formats (Hansestadt Hamburg, 2016, 2018a).

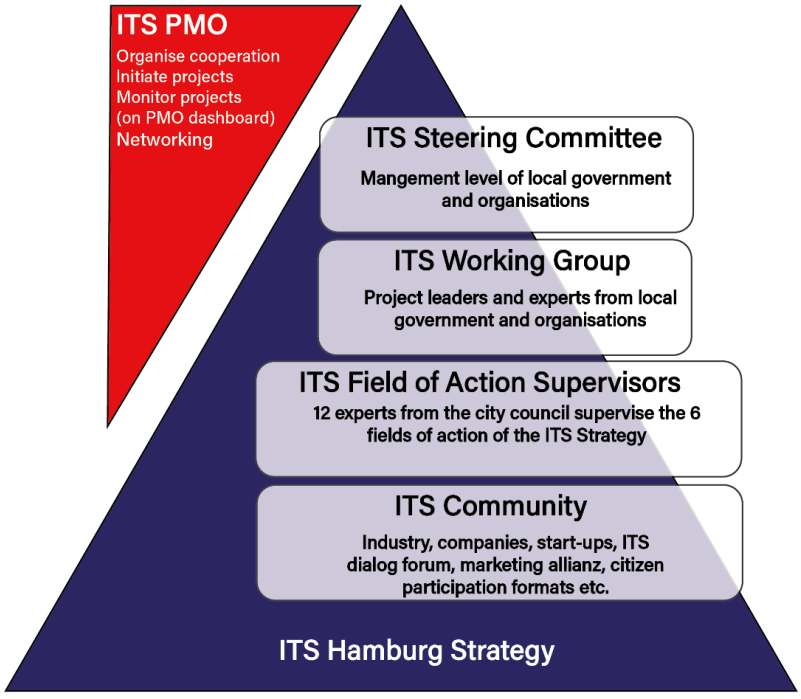

Figure 6 ITS Hamburg management structure. Adapted from (Hansestadt Hamburg, 2021b).

2.2.2. Boroughs (Bezirke) of Hamburg

The local government of Hamburg is divided into seven boroughs (Bezirke). Every borough has its own district office that carries out administrative tasks that can best be dealt with locally. Concerning traffic, the district offices are responsible for the smaller streets, and the City-State of Hamburg takes care of the main road network. In general, the boroughs have closer contact with the citizens because of their smaller size (Expert 2, 06/04/2021; Hansestadt Hamburg, n.d.a).

2.2.3. ITS Hamburg

The need for transportation in Hamburg is increasing. Transport is vital for a city to transport people to work, study or leisure activities. Also, goods need to be transported. In Hamburg the transportation of goods is an essential element of its ITS strategy. The port of Hamburg is the busiest harbour of Germany and the third-biggest container terminal in Europe, with 126.3 Million Tons of transported goods in 2020 (Hafen Hamburg Marketing e.V., n.d.; Hansestadt Hamburg, 2016). The city wants to prevent the increased demand for mobility leading to more motorised private modes of transport like cars (Hansestadt Hamburg, 2016, 2018a).

Hamburg aims to use technological development opportunities to improve the cities' liveability and economic development with the ITS strategy. The first strategy was decided in 2016. The city council applied to host the ITS World Congress in Hamburg and established the PMO in 2017 (see chapter 2.2.1.). In the same year, the city officially got the allowance to hold the congress. A progress report of the strategy was published in 2018. In October of 2021, the ITS World Congress will be held in Hamburg (Hansestadt Hamburg, 2016, 2018a).

The city of Hamburg follows the following definition of ITS Deutschland:

„ITS umfasst alle intelligenten Verkehrssysteme und Anwendungen, die den Verkehr durch den Einsatz modernster IT-Technik sicherer, nachhaltiger und effizienter machen. Dies sind z.B. Fahrerassistenzsysteme, Auto-Auto-Kommunikation (Car2Car), Auto-Infrastruktur-Kommunikation (Car2X), Mobilität als Service (MaaS), Informations- und Bezahlsysteme per Smartphones für den Öffentlichen Verkehr und digitale Lösungen für den Hafen und Logistikbereich." (Hansestadt Hamburg, 2021b, p. 4).

„ITS encompasses all intelligent traffic systems and applications that make traffic safer, more sustainable and more efficient using the latest IT Technology. Such technologies are, for example, driver assistance systems, car-to-car-communication, car-to-infrastructure-communication, Mobility as a Service, information and payment systems via smartphone for public transport and digital solutions for the port and in logistics" (Own translation from the original German quote above).

In the quote above, the bicycle is not explicitly mentioned, as Behrendt (2019) also criticized in her research on policy documents by the European Commission.

The six fields of actions of the ITS Hamburg strategy in which the different ITS projects are assigned are visualised below (figure 7). Different can have overlapping or conflicting interests. Potential conflicting interests are dealt with by the PMO (Hansestadt Hamburg, 2018b).

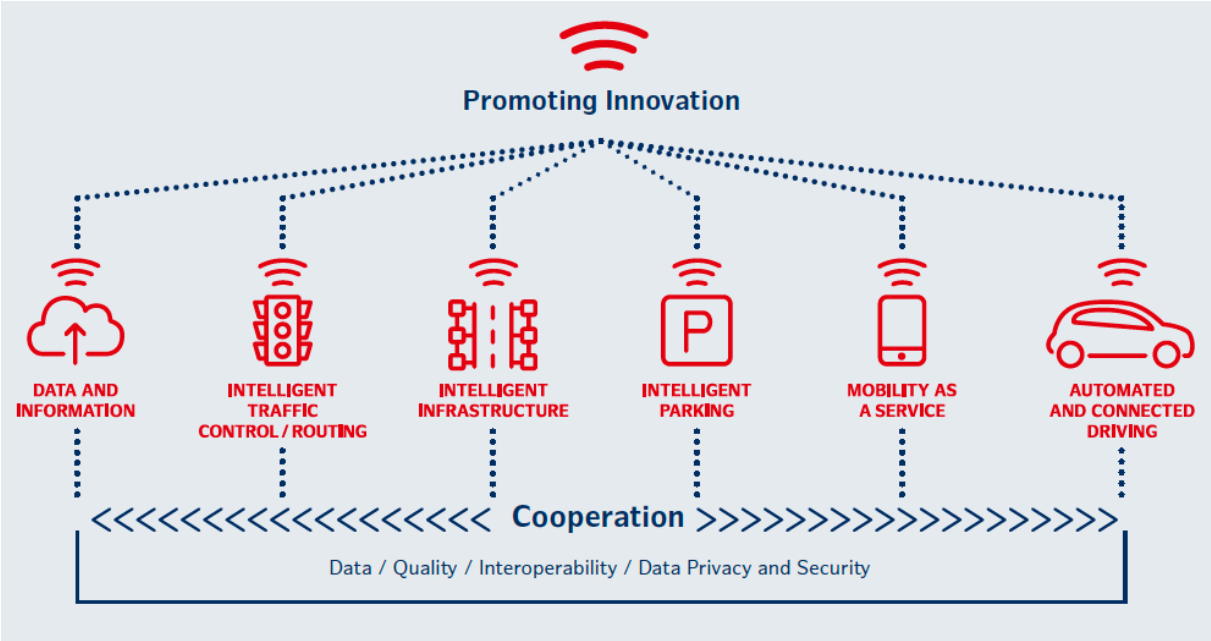

Figure 7 Areas of action ITS Hamburg strategy (Hansestadt Hamburg, 2019a).

As explained in the introduction, the ITS objectives are:

- Increase traffic safety;
- Reduce traffic-related environmental impact;
- Increase the reliability and efficiency of the transport network;
- Good and safe distribution of information;
- Stimulate innovation

Since the strategy was published, various projects were initiated, many of them in strong cooperation with private parties and scientific institutions. To monitor the individual projects the fields of actions are connected to quantifiable indicators. For example, in the MaaS category, the objective is to have a mobility platform that allows for the planning and payment of multi-modal trips among all mobility providers in the city by 2030 (Hansestadt Hamburg, 2016, 2018a).

Open data

Open data is highly valued in Hamburg. In 2012, the city council introduced the transparency law (HmbTG). The law is a prime example of open data sharing within Germany. It obliges the city to make official information publicly available for free. This information is shared on the Urban Data Platform and the Transparency Portal of the city. This is beneficial for external parties and the authorities themselves have quicker access to the data they need. The open data can be found on online[1] (Bohlens, 2020).

2.2.4. Hamburg's mobility transition

Objectives

The City of Hamburg aims to lower emissions caused by traffic through a mobility transition. However, in a growing city like Hamburg, this is not easy. Therefore, the city wants to stimulate public transport, cycling, walking and new sharing services for urban traffic. Hamburg should become a bicycle city. The inner city should become practically car-free to promote cycling and bicycle and walking infrastructure is improved citywide. Also, public transport is expanded. Within

[1] https://transparenz.hamburg.de/, http://www.urbandataplatform.hamburg/

the coming 20 years, 36 new train stations are planned. The first interim goal is to increase the modal split of the sustainable modes of transport (walking, cycling and public transport) combined from 64 per cent in 2020 to 80 per cent in 2025 (Tjarks, n.d.).

The ITS strategy of Hamburg is a vital tool to reach the cities mobility transition objectives. Through the intelligent connection of different modes of transport, making sustainable transport choices should become easier. By 2030 the nearest public transport stop should not be more than 5 minutes away in the whole city (Hansestadt Hamburg, 2016, 2018a, 2019c; Tjarks, n.d.).

The objectives are also backed up by the collation agreement 2020-2025 between SPD (Labour Party) and die Grüne (the Green Party), the goal was set to increase the modal split from 22 percent in 2017 to 30 percent in 2030. Also, the trips taken by bicycle should increase to at least 25 percent by 2030 (Hansestadt Hamburg, 2020).

Interest groups

There are different lobby groups for sustainable mobility active in Hamburg. For cycling, there are among others the ADFC (the Cyclists' Union) and Radentscheid Hamburg. Radentscheid Hamburg is a popular initiative that aims to improve cycling conditions in Hamburg. More than 22,000 citizens from Hamburg signed the petition of the Radentscheid. With the ruling political parties SPD (Labour Party) and die Grüne (the Green Party) the lobby group negotiated several measures to make cycling in Hamburg more inclusive. The politicians agreed with the Radentscheid that segregated bicycle paths on every major urban road should be built. Also, the interests of cyclists and pedestrians should become more priority in construction site design and crossings are made safer. The latter point entails that so-called ‚cycle lanes in the central position' are not newly build anymore. These bicycle lanes are criticized because conflicts between cyclists and other vehicles may occur when vehicles cross the bicycle lane, as shown in figure 8. The curve radius on crossing should also be reduced to slow down turning vehicles. However, the lobby group and city council could not agree on every point. The city, for example, did not join the pilot project that tests whether protected intersections like in the Netherlands can be built, and strong commitments regarding minimum financing for bicycle infrastructure could not be given (Kienscherf & Tjarks, 2020; Radentscheid Hamburg, 2020).

Figure 8 Car crossing the 'bicycle lane in the central position' at the Jungiusstraße in Hamburg. Own image.

Barriers of cycling

Wang (2018) researched the barriers to pro-cycling policies in Hamburg. She identified that the major barriers are physical, political, and institutional. In her conclusion, she suggests that a bicycle coordinator should be hired to oversee the measures. Hamburg took a step in the right direction by being the first German state to ground an authority for mobility transition in 2020 (Behörde für Verkehr und Mobilitätswende). The objective of the new authority is to keep traffic running in Hamburg while reducing emissions through a mobility transition to more sustainable modes of transport like public transport and cycling (Hansestadt Hamburg, n.d.a). The promotion of cycling in Hamburg started roughly in 2008 when the green party was voted into parliament. Many citizens of Hamburg voted the green party because of the green's placed themselves as protagonists of more bicycle-friendly policies (Lanzendorf & Busch-Geertsema, 2014; Wang, 2018).

The modal split of cycling in Hamburg is already comparably high (2017: 22 per cent) (Hansestadt Hamburg, 2020). Which is much more than the 5 per cent (2011) in Wiesbaden (Germany) but less than in Münster (38 per cent in 2008) (Lanzendorf & Busch-Geertsema, 2014). However, bicycle conditions in Hamburg are still not that great. According to the German Cyclists federation (ADFC) survey, respondents value cycling conditions in Hamburg with an unsatisfactory grade. Out of the fourteen biggest cities in Germany, Hamburg scored seventh place. Respondents mainly complained about narrow and not well-maintained bicycle infrastructure (ADFC, 2020).

To increase the cycling modal split in Hamburg, mainly the more reluctant, vulnerable, and practical cyclists need to be facilitated more to get people on the bike that are not as likely to cycle (chapter 2.1.3.). Sadly, the increasing number of cyclists on Hamburg's roads also goes hand in hand with an increasing number of crashed cyclists. In 2020, the highest amount of bicycle accidents was reported since 2010 (2,735). Three cyclists died in Hamburg's traffic (Statista, 2021). Safety is, therefore, still an important issue in planning for cycling in Hamburg.

Figure 9 News article from the 23rd of July 2021. Translation: Hamburg: "Van hits cyclist when turning – dead" (Gaertner, 2021).

Hamburg's bicycle infrastructure

As a Hamburg citizen and regular cyclist, the following sub-chapter shows some subjective impressions of Hamburg's bicycle infrastructure to give the reader a general feeling about the network. It does not aim to give a representative view over the whole city area.

Figure 10, shows the Eiffestraße close to house number 634. The road functions as a main arterial road (B5) from the city centre towards eastern suburbs like Bergedorf. The cycle track is narrow and in bad condition. Bad sight lines for vehicles turning right over the cobblestone driveway are a risky situation for cyclists.

Figure 10. Narrow bicycle path with bad surface and broken glass next to four lanes of motorised traffic. Hamburg, Eiffestraße. Own image.

The parallel bicycle path through the Grünzug Hammer Landstraße is around 500 meters north of the Eiffestraße and is much more pleasant to ride (figure 11). It is a route separated from motorised traffic and part of the main bicycle route 8 of Hamburg's Veloroute network. The path is relatively wide, although slightly narrow from a Dutch perspective. According to the Dutch CROW standards, a frequently used path with two-way traffic should be at least 3.5 to 4 meters wide (Kennisplatform CROW, 2017). The shown bicycle path is around 3 meters wide and separated from the sidewalk with road studs.

Figure 11 Decent bicyle path at Grünzug Hammer Landstraße. Own image.

Figure 12 shows Hamburg's widest bicycle lane along the Ballindamm leading from the city centre to the north-east. The one-way bicycle lane is 4.75 meters wide in one direction and 2.25 meters in the other (Welt, 2020). However, the bicycle lane is not physically separated from other road users, resulting in illegal usage.

Figure 12 Hamburg's widest bicycle lane along the Ballindamm. Own image

2.3. Conceptual framework

The following conceptual framework summarises the main topics of this research and visualises the relations between the different topics (figure 13). The overarching topic is Smart City. Within the concept Smart City, ITS is a crucial element. In this research, two elements of ITS are investigated more thoroughly. Smart Velomobility and Hamburg's ITS strategy. Inspired by the Golden Circle of Simon Sinek with the 'why', 'how', and 'what' (Eelants, 2017), it is investigated why ITS Hamburg should incorporate Smart Velomobility and how they can integrate Smart Velomobility in Hamburg's ITS strategy. Furthermore, what should be done to integrate Smart Velomobility in Hamburg's ITS strategy will be answered.

Next to the ITS strategy, the City of Hamburg has ambitious objectives for a mobility transition away from individual transport towards more sustainable modes of transport. The extent to which both strategies are connected and should be connected will be answered in this thesis.

MRQ: To what extent can Smart Velomobility contribute to Hamburg's wanted traffic transition?

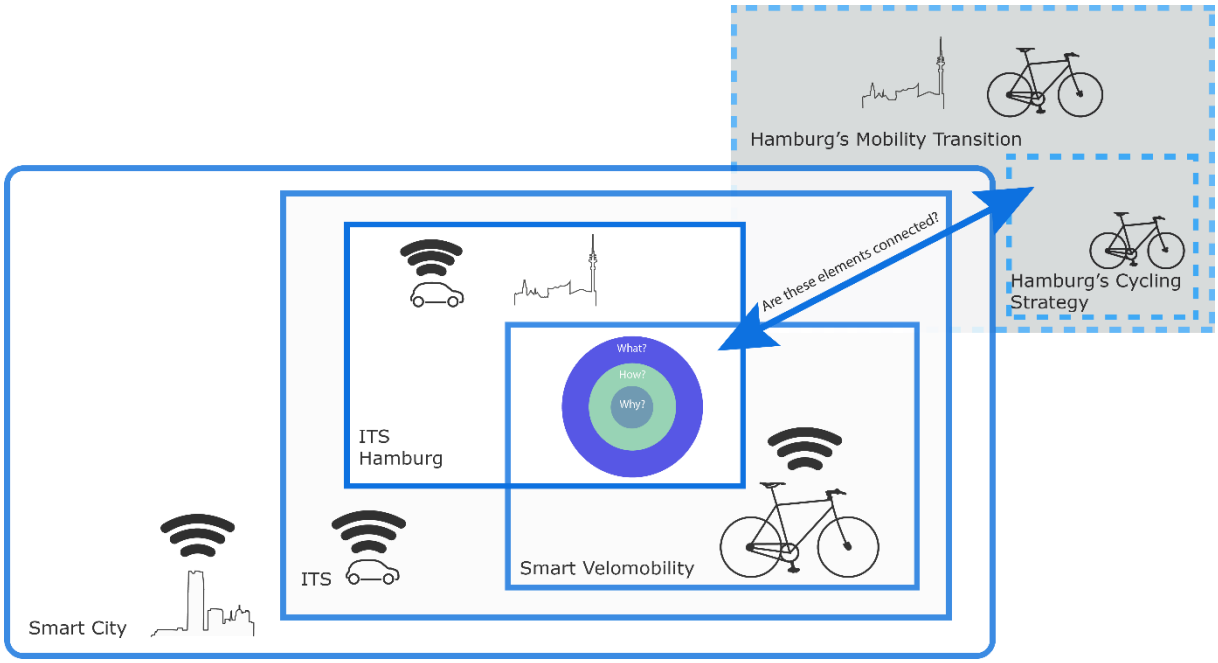

Figure 13 Conceptual model. Circle inspired by Simon Sinek's golden circle.

3. Methodology

This chapter gives an overview of the three methods (literature review, policy analysis, and semi-structured interviews). It concludes with the ethical considerations that were considered.

3.1. Research design

Case studies are especially useful to evaluate broad and complex initiatives. The integration of Smart Velomobility within the overall ITS Hamburg strategy is highly complex because various fields of action and many different stakeholders are relevant (Yin, 2013). Therefore, I chose to conduct a case study.

There are two main challenges in conducting case studies, validity and generalisation. Primarily when only one or a limited number of cases are studied. To overcome this issue Yin (2013) suggests using analytic generalisations in case studies instead of statistical generalisation. With numeric

generalisation, a high number of cases is needed. However, this strategy would mean that in-depth research is required for multiple ITS strategies, which would be out of the scope of a master's thesis.

"By analytic generalization is meant the extraction of a more abstract level of ideas from a set of case study findings – ideas that nevertheless can pertain to newer situations other than the case(s) in the original case study. For case study evaluations, the analytic generalization should aim to apply to other concrete situations and not just to contribute to abstract theory building." (Yin, 2013, p. 325).

In analytic generalisation, the researcher compares results from a case study to an existing theory to see if that theory can be supported or not (Yin, 2014). In this research, the theory of Behrendt (2019) that suggests that Smart Velomobility is generally absent from the Smart City debates, is tested for the ITS Hamburg case.

The findings from this research cannot draw a general conclusion about the integration of Smart Velomobility in ITS strategies. Nevertheless, it allows for a better understanding of such an intervention and its outcomes. Furthermore, the generalisations of this single case study can be interpreted within the broader scientific discourse and thus contribute to cumulative knowledge about the studied topic (Yin, 2013).

The generalisation of case studies is important because they allow for the transfer of lessons within the same country and between different countries (Yin, 2013). To allow for such transfer learning, the city of Hamburg was picked. This city is already known for its Smart City and ITS projects. As explained before, Bitkom awarded the City of Hamburg the smartest Smart City in both the general and mobility categories (Bitkom, 2021). The logic behind this is that a city that is ranked high on the Smart City Index and that also is the second biggest city in Germany (Hafen Hamburg Marketing e.V., n.d.), has a relatively high capacity to innovate and experiment with different Smart City initiatives like Smart Velomobility. As Yin (2013) also states, a solid empirical foundation is achieved ideally through in-depth research of a case in its real-world context. Having a case executing a variety of Smart City projects allows for stronger generalisations of the research questions. Furthermore, I chose to do an internship at Orange Edge, an office for urban planning and mobility research for personal reasons, and learn more about Hamburg from planning practice (Taylor, 2016). The latter benefited this research because I was granted access to the non public Hamburg ITS PMO Dashboard because I contribute to the ITS.City.Street.Guide, one of the ITS Hamburg projects. Later in this chapter, I will explain more about the ITS.City.Street.Guide.

Data triangulation was applied to improve the ability to make generalisations about the results from this case study. Triangulation is a mixed methods research approach that increases the confidence in findings in a case study through the use of quantitative and qualitative methods (Creswell & Plano Clark, 2018; Yin, 2013). Data triangulation is especially useful for a one case study because it results in greater confidence in the study's overall findings and increasing validity (Yin, 2013). Three methods are used: a literature review, a policy analysis, and semi-structured expert interviews.

3.2. Literature review

Relevant scientific literature needs to be reviewed and discussed to develop a theoretical framework. Research started by finding a research topic for the research proposal. After this, the framework of Healey & Healey (2016) was used as a tool for further literature research (figure 14). After this, the key terms were identified for the topic. These terms are Smart City, ITS (Hamburg), Smart Velomobility, (Hamburg's) mobility transition and (Hamburg's) cycling strategy. These key terms are also visualised in the conceptual model in chapter 2.3. With these key terms, search terms that relate to the chosen topic were defined. There are broader terms like sustainable urban mobility, related terms such as Smart City and narrower terms like Smart Velomobility or smart cycling. This order may suggest that literature research is a linear process; however, it is a messy process in practice. The search terms are used for different search engines. Academic search engines

such as SmartCat and Google Scholar but also the regular search engine Google was used. A variety of sources ranging from scientific papers, scientific e-books to websites like the website of Hamburg and news articles, were evaluated, skimmed, critically read and potentially relevant sections were marked. Also, citations within papers and books were used to form the theoretical framework.

For avoiding plagiarism, it is essential to cite the work of others correctly. It helps to write down the page number(s) if a later review of the source is needed (Healey & Healey, 2016). To manage the variety of sources, I used the citation manager Citavi (version: 6.3.0.0).

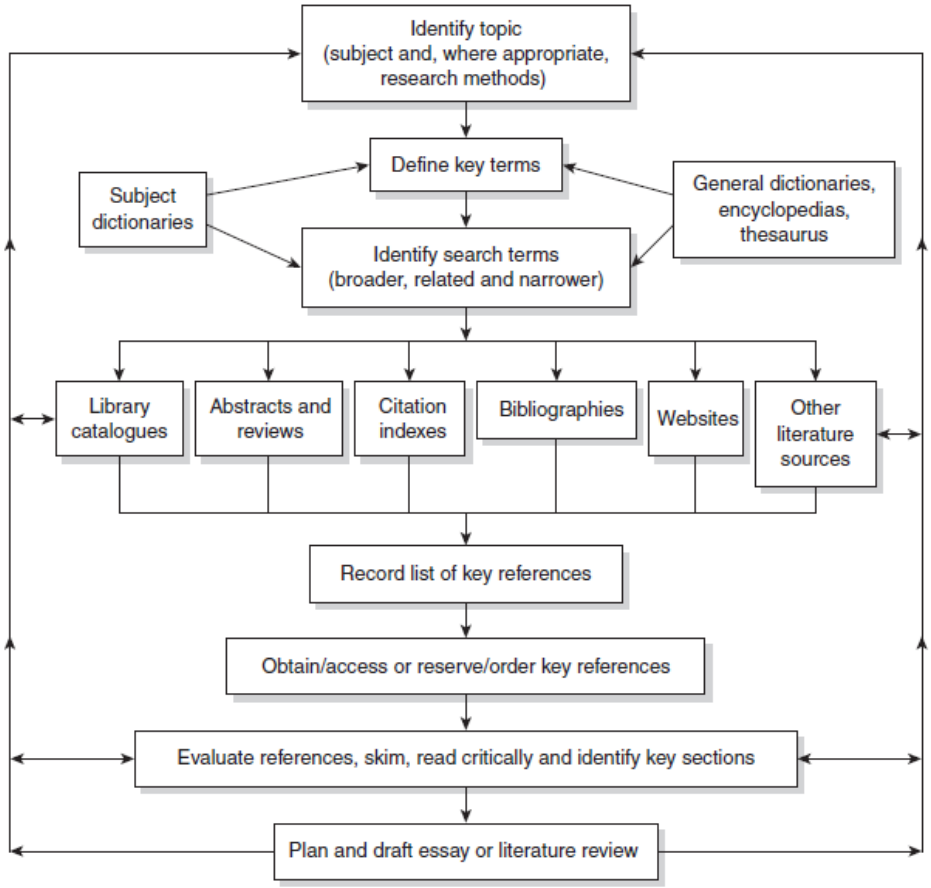

Figure 14 A framework for undertaking literature research (Healey & Healey, 2016).

3.3. ITS Hamburg analysis

The table below shows how the ITS Hamburg project are analysed (figure 15). Projects were first analysed for their relevance for cycling using publicly available sources from the City of Hamburg and the PMO Dashboard. The relevance for cycling is expressed in one to three points. This score multiplies the other points that were assigned to the different categories. Three points for projects that are fully cycling related, two points for projects that are partly cycling related and one point for projects that are not directly cycling related but that can support cycling. An example of such a project is testing autonomous vehicles and how they deal with cyclists. Projects that are not at all cycling-related nor that can support cycling were left out from the analysis.

Out of the around 200 ITS projects, Hamburg selected 42 flagship projects (anchor projects) that are particularly important to reach the ITS Hamburg objectives (Hansestadt Hamburg, 2018b)). These projects form the basis for the other ITS projects. At the ITS World Congress, the (preliminary) results will be presented to the visitors.

The analysis of the projects is focussed on the anchor projects due to the following reasons:

- The anchor projects are particularly representative for the ITS objectives of the city of Hamburg;
- All anchor projects show at least preliminary results;
- Information is publicly available about the anchor projects instead of most other projects.

Relevance for cycling

First, the anchor projects are filtered for their relevance for cycling.

0 points: no relevance for cycling, these projects are not further considered in the policy analysis.

1 point: no direct link with cycling but may support cycling. (e.g., HEAT).

2 points: partly cycling related. The bicycle is one of the modes of transport that is considered in this ITS project.

3 points: this project is fully cycling related. Only PrioBike HH and HaRaZäN got 3 points.

Weighting

After that, projects were given points for several factors. It ranged from the most important factors ‘safety and reliability’ to ‘comfort and experience’. These hierarchies of importance were derived from the Bicycle Pyramid developed in the Interreg BITS project, described in chapter 2.1.3. (Interreg North Sea Region, n.d.).

Safety & reliability

According to the Bicycle Pyramid, ‘safety & reliability’ is the most crucial element (chapter 2.1.3, figure 2) (Interreg North Sea Region, n.d.). Therefore, the points scored in this category is multiplied by 3.

Speed & convenience

Speed and convenience are the second most important elements of Smart Velomobility (Interreg North Sea Region, n.d.). The points scored in this category are multiplied by 2.

Comfort & experience

Comfort and experience are the least essential elements of Smart Velomobility, according to the Bicycle Pyramid (Interreg North Sea Region, n.d.). The points scored in this category are not multiplied.

Gimmick

The last category, ‚gimmick‘ was added to the analysis schema. These bonus points (0,5 * N) are added for the so-called fun-factor or gimmick factor a particular application gives to the user. As explained before (chapter 2.1.3.), some vulnerable groups may not profit that much from smart cities (Lefevre, 2014; McLaren & Agyeman, 2019; Botello et al., 2019). These groups are likely to profit more from the other elements that are therefore also valued higher. However, there are other technology-interest groups for which gimmicks can contribute to their bicycle experience.

Calculation

The final score of every project was calculated with the following formula.

Formula: *a * ((3*b) + (2*c) + (1*d) + (0,5*e)) = x*

Formula in text: *Relevance for cycling * ((3*safety & reliability) + (2*speed & convenience) + (1*comfort & experience) + (0,5*gimmick)) = Score*

Example: project A: *1 * ((3*3) + (2*2) + (1*2) + (0,5*3)) = 17.5*

Project B: *3 * ((3*2) + (2*1) + (1*1) + (0,5*2)) = 30.*

Even though fictional example A scores higher in all four categories, the total score is 17.5 points, which is much lower than the score of example B (figure 15). Because example B is fully cycling-related, its scores in the categories were valued three times more than example a.

Project	Relevance for cycling (1-3) - a	Safety & reliability (3) – b	Speed & convenience (2) – c	Comfort & Experience (1) – d	Gimmick (0,5) – e	Score
Project A	1	3	2	2	3	**17.5**
Project B	3	2	1	1	2	**30**
Project C	1	1	2	2	3	**11.5**

Figure 15 Example table policy analysis.

3.4. Qualitative interviews

Semi-structured interviews were conducted with five different experts. An overview of the interviewees is given in table 3. Two interviewees are from Hamburg and directly work for the execution of Hamburg's ITS strategy. Two additional experts not from Hamburg but with knowledge about ITS Hamburg were interviewed. Expert 3, was interviewed for her expertise on cycling and inclusivity in urban mobility. And lastly, expert 5 is an ITS expert from a private firm outside of Hamburg that works for ITS Hamburg projects. Also, Ronald Jorna, an expert on the interface of cycling and ITS from the Dutch consultancy firm Mobycon was consulted. He is also working for the Interreg BITS project that was discussed in chapter 2.1.3.

A standard interview guide was developed for the semi-structured interviews (see appendix). For every interview, the interview guide was adapted to the knowledge and expertise of the interviewee. Four out of five of the interviewees were anonymised. The interview with Ronald Jorna is not anonymous upon his request. Expert five requested not to record the interview; therefore, there is no transcript available for the 5th interview. The four other interview transcripts are available upon request by the author and after written permission from the interviewee.

Interview partner	Profession	Based in	Date	Reason for interview
Expert 1 Ronald Jorna	Strategic adviser mobility at Mobycon - expert on cycling and ITS	The Netherlands	06/06/2021	Find out the risks, disadvantages and benefits/ opportunities of Smart Velomobility measures
Expert 2 Anonymous	Expert traffic and infrastructure data at city of Hamburg	Germany, Hamburg	06/04/2021	Prioritizing between Smart Velomobility and ITS objectives. Political debate and citizen participation, role of ITS in Hamburg's traffic strategy
Expert 3 Anonymous	Cycling expert at a private firm with a focus on inclusivity	Germany, outside of Hamburg	06/11/2021	Opportunities and risks of Smart Velomobility from a bicycle infrastructure expert perspective
Expert 4 Anonymous	Project coordinator of ITS projects in Hamburg	Germany, Hamburg	06/17/2021	Role of ITS congress, Prioritizing between Smart Velomobility vs. other ITS objectives
Expert 5* Anonymous	Project manager / ITS expert at a private firm	Germany, outside of Hamburg	06/18/2021	More general role of Smart Velomobility within the ITS strategy of Hamburg

*Table 3 Interview partners. *transcripts are available for all interviews except for the interview with expert 5.*

Data analysis

After the interviews were conducted, all recorded interviews were transcribed with Amberscript. Then relevant data was labelled and coded in Atlas.Ti (version 9.1.5.0). After this, the different codes were categorised and connected. Finally, the outcome of the interviews was analysed and described in chapter 4.2.

3.5. Ethical consideration

Two main ethical issues in conducting interviews are confidentiality and anonymity (Longhurst, 2016). Interviewees should not be harmed due to their participation in this research. Therefore, it is essential to protect the privacy of the interviewees. Furthermore, ethical behaviour assures a favourable climate for the researcher to stay trustworthy. Lastly, as a student at the University of Groningen, the university expects me to behave ethically (Hay, 2016).

The debate about the mobility transition is highly political (Koglin & Rye, 2014). Therefore, to protect the interview partners and let the interviewees speak freely, I suggested that the interview will be transcribed and processed anonymously in the introduction of the interview. One interviewee, Ronald Jorna, wished that his name and the company he works at would be mentioned. Another interviewee (expert 5) said that he or she does not want to be recorded. For this interview, there are thus only notes available from the interview.

Additionally, participants were told that they could withdraw from the research at any time without explanation. Obtained data was stored on a password secured cloud storage to ensure that the data remains confidential. After finishing this research, the recordings were deleted (Longhurst, 2016).

Ideally, the interviews would be conducted during a physical meeting. However, to prevent unnecessary travel and the potential spread of COVID-19, all interviews were conducted digitally.

PMO ITS dashboard

Expert 4 granted access for me to the Project Management Office (PMO). On the PMO ITS Dashboard, the project descriptions of around 200 ITS Hamburg project can be seen. However, I had to state that I would use the information on the dashboard confidentially. This was needed for two reasons: commercial partners do not want their competition to have access to their project details, and the project descriptions are not suitable for the public because the texts contain jargon and are not finally edited for publication (Expert 4, 06/17/2021).

ITS.City.Street.Guide.

Through my internship at Orange Edge, an urban planning office, I got in touch with Prof. Dr. Stefanie Bremer. She kindly offered me to join her group of students from the University of Kassel with the ITS.City.Street.Guide project. The publication aims to give an insight into the future of Hamburg's street spaces, taking into account ITS projects from six fields of action. A short description of the outcomes of this thesis will also be part of the street guide. The sponsor of the project is the Deutsche Shell Holding GmbH. They, however, did not have any influence on the results of my research.

4. Results

In this chapter, the outcomes of the policy analysis and expert interviews are presented.

4.1. Policy analysis

Smart Velomobility Index

In the table 4 below, the outcomes of the policy analysis are visualised. Chapter 3.3 describes how the scores are calculated. The five best scoring projects and three further interesting ITS solutions are illustrated in short below. Further details about the anchor projects that are not described in this thesis can be found on the website of ITS Hamburg.[2]

[2] https://www.hamburg.de/its/

Project	Relevance for cycling (1-3)	Safety & reliability (3)	Speed & convenience (2)	Comfort & experience (1)	Gimmick (0,5)	Score
1. PrioBike-HH	3	3	3	3	3	58.5
2. TLF 2.0.	2	3	3	3	3	39.0
3. GeoNetBeacon	2	3	3	3	3	39.0
4. HaRaZäN	3	1	2	2	2	30.0
5. BiDiMoVe	2	3	1	1	2	26.0
6. HVV Switch	2	1	2	3	3	23.0
7. The Good turn	2	1	2	3	3	23.0
8. TIMS demonstrator	2	1	2	3	2	22.0
9. Roads	2	1	2	2	2	20.0
10. SmartOpenHamburg	2	0	3	3	2	20.0
11. aVME	2	1	2	2	2	20.0
12. DigITALL	2	1	1	1	1	13.0
13. TIQ	1	3	0	2	2	12.0
14. HEAT	1	1	2	3	3	11.5
15. TAVF Hamburg	1	1	2	3	3	11.5

Table 4 Smart Velomobility Index.

The top 5 anchor projects

The top 5 anchor projects came out of the analysis with the highest value for Smart Velomobility. Projects scored between 26 and 58.5 points. A short description of the projects is given as well as an explanation about why the project scored a certain amount of points in the different categories.

1. **PrioBike-HH**

With a perfect score on every category and a 'relevance for cycling' of 3, PrioBike-HH scored the maximum points. The project is in cooperation with the University of Dresden and traffic software developer INAVET GmbH. PrioBike-HH optimises traffic lights for important bicycle routes. With the technique, the number of stops needed at traffic lights can be reduced. Additionally, an app should be developed in which cyclists are advised which route is optimal for them and for how long the traffic light will show a green light (Hansestadt Hamburg, 2021b; Wauer, 2021).

Furthermore, drivers of motorised vehicles will be equipped with driver assistance systems that should warn drivers for approaching cyclists. Another added value is that the generated data like number of cyclists, average speed, dangerous encounters, and traffic density is planned to be shared in open data platforms. This follows the principle of the Data Reflex as described in chapter 2.1.3. (Hansestadt Hamburg, 2021b; Jorna & Kleine; Province of Antwerp, 2020; Wauer, 2021).

2. **Traffic Light Forecast 2.0**

The Traffic Light Forecast 2.0 is a research project funded by the German federal government that sends traffic light switching times to traffic lights assistants for different modes of transport. Road users will then be advised to adjust their speed, so they ideally do not have to wait for a red light. Unique about this project is that the technique is non-discriminatory and manufacturer

independent. Large organisations, developers, and end-users can use the data published on the cities' Urban Data Platform. This project scores 2 points for its bicycle relevance because it is not only a Smart Velomobility project. For each further category, the TLF becomes the maximum number of points (Hansestadt Hamburg, 2021b; Wauer, 2021). With 39 points, this project ends on a shared second place with the GeoNetBeacon.

3. GeoNetBeacon

The description of this project starts with a short and social media analysis on why this project is essential to improve cycling conditions in Hamburg.

As can be seen from the tweets posted by @Flow30924731, @lebenswerteCity and @VelorouteHH (Flow30924731 et al., 2021), it is not always easy to identify as a cyclist where the bicycle route is blocked due to road works. Twitter user @Flow30924731 complains to the Authority of Traffic and Mobility Transition and senator of that Authority, Anjes Tjarks that a vital bike route is just blocked without clear information for the cyclists and without a direct alternative. The user cynically adds that at least the motorised individual transport can keep running on three lanes. Another twitter user that goes with the pseudonym @lebenswerteCity replies by asking why those roadblocks are not just added to the cities Geoportal. To this question, @VelorouteHH responds by suggesting that it probably has to do with the high effort that comes with adding traffic blocks and other road works to the online portal. GeoNetBeacon and the Roads (place 9) should bring a solution for this.

Figure 16 Tweets from users @Flow30924731, @lebenswerteCity and @VelorouteHH about blocked bike routes.

GeoNetBeacon is a system of traffic beacons with sensors that can be used for the cordoning of construction sites. Live information coming from the intelligent traffic beacons is linked to Hamburg's previously mentioned Urban Data Platform. Private parties and developers of applications can use this open data and the federal German government funds the project (Hansestadt Hamburg, 2019a, 2021b). Because the project considers all road traffic members, the project gets two points for 'relevance for cycling'. All other categories scored the total number of points. With 39 points, this project ends on a shared second place with TLF 2.0.

4. HaRaZän

HaRaZän is a federally funded project and next to PrioBike-HH, the second fully cycling-related project. For 'relevance', the project thus becomes 3 points. Currently, 55 fixed bike counters in Hamburg detect cyclists with heat sensors. Unlike the other projects from the top 5, this has no direct influence on the cyclists 'safety & reliability'. Nevertheless, the data can be used as a basis for the expansion of bicycle infrastructure. Therefore, the project becomes 1 point for this category. For the categories 'speed & convenience', 'Comfort & experience' and 'Gimmick', the project becomes 2 points each. Data that is generated in the project is publicly shared. External software developers

can make use of this data to develop intelligent solutions. However, to the author's knowledge, no developer has made use of the data so far. The project would have scored higher if app developers had already developed solutions that benefit one or more of the Smart Velomobility Index categories (Hansestadt Hamburg, 2021b).

5. BiDiMoVe

BiDiMoVe is a federally funded dynamic system that prioritises busses at traffic lights. A further element is that bus drivers are warned of oncoming bicycle traffic when they turn right. This increases safety for cyclists at crossings. Therefore, this project becomes 3 points for 'safety and reliability. Because the main aspect of the project is to improve bus services, the project becomes 2 points for 'relevance for cycling'. In the categories 'speed & convenience' and 'comfort & experience' the project scored only 1 point each. However, because 'safety & reliability' is weighted more, BiDiMoVe still achieved fifth place with 26 points (Hansestadt Hamburg, 2021b).

Other interesting projects

6. HVV Switch

HVV Switch is a MaaS app and critical element in Hamburg's mobility transition- and ITS strategy. The app should eventually include all relevant mobility suppliers within the city. The classical public transport is strengthened with sharing services. Over 70 HVV points (mobility hubs) with shared bikes, shared cars and bike and ride stations are scattered over the city's territory. The stations are located near metro- and train stations and other strategic locations. Currently, the app only offers public transport, ride-sharing service MOIA[3] and car-sharing facilitated by Sixt. The Hamburg city bike (Stadtrad) is not yet integrated into the app, although there are often shared bike stations at HVV Switch points (Hamburger Hochbahn AG, n.d.; Hansestadt Hamburg, 2021b). Because there are several forms of mobility at the Switch points, the 'relevance for cycling' gets 2 points. For 'safety & reliability', the project becomes only 1 point. Benefit in this category is that the locations are conveniently located, preventing users from having to look for their shared vehicle in the streets at night. When the shared bike system is integrated into the HVV Switch app, the points for 'speed & convenience' would increase from 23 points to 27 points. With this score, the project would be among the five best Smart Velomobility projects in the Smart Velobility index of Hamburg.

[3] MOIA is a shared ride systems owned by Volkswagen which operates in Hamburg and Hanover (MOIA (n.d.)

Figure 17 HVV Switch point at Dammtor train station Hamburg. In the front the shared bicycle system (Stadtrad), behind that electric car-sharing and, in the back, a conventional petrol station.

9. Roads & 12. DigitaII

Roads is a tool to coordinate urban road works. It is an interactive, helpful instrument for the city's traffic coordinators to make intelligent decisions concerning road works. All the needed data about current road works, events, detours and roadblocks are visualised in an interactive touch environment (Hansestadt Hamburg, 2021b). The project considers all road users and therefore becomes 2 points for 'relevance for cycling'. It may only have a low influence on the 'safety and reliability' when projects road works are more efficient; therefore, it gets 1 point for this category. For the remaining categories, the project becomes 2 points respectively because cyclists are likely to profit from better coordination in urban road works. This results in a score of 20.

The DigitaII project is comparable with the Roads tool. It gives an overview of all building projects in the city. The web-based 'Bauweiser' application helps decision-makers with the approval process and route finding for new infrastructure (Hansestadt Hamburg, 2021b). Because it is likely to have less impact on the quality of cycling it gets only 13 points.

4.2. Expert interviews

4.2.1. Advantage of Smart Velomobility

All interview partners were asked to evaluate the potential advantages and disadvantages of Smart Velomobility. The codes that are relevant for this are visualised below (table 5).

	1: Interview 3 (26)	2: Interview 4 (51)	3: Interview 5 (18)	4: Interview 2 (44)	5: Interview 1 (33)	Totals
SV: Advantage: communication (2)	1			1		2
SV: Advantage: digitalisation to improve multi modal trips (8)		1	2	2	3	8
SV: Advantage: experience comfort (2)					2	2
SV: Advantage: gamification (1)					1	1
SV: Advantage: green waves (4)		1		3		4
SV: Advantage: planning with data (17)	4	7		4	2	17
SV: Advantage: safety (10)	1	2	3	1	3	10
SV: Advantage: speed (2)					2	2
SV: Advantage: tool to promote cycling (1)		1				1
Totals	6	12	5	11	13	47

Table 5 Advantages of Smart Velomobility.

The most frequently mentioned code was *planning with data.* In four out of five interviews, Smart Velomobility's benefits for urban planning to use newly generated data for a more adaptable way of planning was mentioned.

Ronald Jorna, expert 2, and 4 mentioned solutions that would make trips by bike faster. The codes *speed* and *green waves,* were used to code these statements.

Having more data as a planner can have several benefits:

Giving data back to the end-user

Ronald Jorna stressed that every ICT solution generates data. Smart Velomobility projects can therefore be used to give the data directly back to the end-user. He gave the example of the data of free parking spots in bicycle parking garages in Utrecht. Signs on street level and within the garage show the cyclist where they can park their bike. This contributes to both 'speed & convenience' and 'comfort & experience' from the bicycle pyramid that was discussed in chapter 2.1.3. According to Jorna, another means of feeding data directly back to the cyclist is, through intelligent traffic lights. Traffic lights can adapt their green cycle to bicycle flows or cyclists can be informed about whether they should cycle a bit faster, keep pace, or slow down to continue without stopping. Another application may be to give a specific group priority at the traffic light. In the Dutch city of Zwolle, the city is experimenting with prioritising bicycle couriers at the traffic lights as is also done with emergency vehicles or busses.

In the project PrioBike-HH, Hamburg is experiment with giving cyclists a head start. Expert 2, an employee of the city of Hamburg focussing on traffic and infrastructure data, stressed that the benefit of a project like PrioBike-HH over green waves for cyclists is that it is functional for cyclists traveling with different speeds. There are for example, cyclists on racing bikes or e-bikes travelling around 25km/h and older people cycling at only 15km/h. For a green wave to function, cyclists must travel at a similar speed. To take into accounts all these groups, other solutions might be better according to expert 2. Having specific data, like the quality of the road surface, offers opportunities to adapt routing apps to the demands of different target groups. Someone with a racing bike may prefer a different street surface than a mountain biker. Furthermore, bicycle data allows for the sharing of information in the city's Urban Data Platform.

Expert 3 stressed the advantages of start-ups like Bike Citizens. This start-up developed an app that tracks users' data, which supports cyclists in taking the safest and less polluted route by giving back the data to the end-user.

The GeoNetBeacon project was mentioned by expert 4. This project is a system of traffic beacons with sensors that can be used for the cordoning of construction sites (chapter 4.1.) (Hansestadt Hamburg, 2019a). Expert 4 said that a frequent issue is that cyclists do not know that roads are blocked, or detours are not signed well. He expressed the hope that with the GeoNetBeacon project, cyclists will be informed better about road works.

Using data for better traffic planning

Several interview partners mentioned the potential data collecting and sharing could have for improving bicycle infrastructure planning.

As said before, Ronald Jorna mentioned that every ICT solution generates data. This data can also be used for better bicycle policies because it gives a better insight into cyclists' behaviour. He also advises making this bicycle data publicly available. This open data can then be used for external app builders to develop new, more innovative solutions (see also the bike citizens app mentioned by expert 3).

According to city employee, expert 2, the city's data about motorised individual transport and bicycle traffic is incomplete even though the city does around 500 to 600 traffic counting's per year. Preferably the city would like to have real-time data and data outside of peak hours / -days:

"Also, wir wüssten gerne mehr über den Radverkehr [in Hamburg] und wir wollen nicht nur so eine Stichprobe an einem Tag haben. Am liebsten hätten wir die Daten rund um die Uhr und in Echtzeit." (Expert 2, 06/04/2021).

„Well, we would like to know more about bicycle traffic [in Hamburg], and we do not want one counting on one day. Preferably we would like to have real-time data around the clock." (Own translation from the original German quote above).

Expert 2 continued by explaining that the city started two data collection projects. One of them is the Automated Traffic Volume Detection (aVME) project consisting of over 2000 thermal imaging cameras that can detect traffic in real-time. When cyclists drive on the road, they will also be detected through this system. The second project is HaRaZäN. Both projects use thermal imaging cameras to count bicycle traffic specifically. This open data will be fed into the bicycle infrastructure databank that is already partly published. Expert 4, who also works for the city of Hamburg, agreed with his colleague that the traffic planners use that bicycle data to speed up bicycle infrastructure planning and that it gives a tool to follow the needs of the cyclists themselves better. Another way to gain data, expert 2 explained, is through an app like DB+. This app lets users collect points for every bicycle trip. These points can then be used at partner shops like the bakery. In return, the city council gets movement data to improve traffic planning.

"Leinpfad ist eine Fahrradstraße an der Außenalster der sehr viel befahren wird und auch teil einer ITS Tour sein wird. […] Die Daten fließen in die Verkehrsplanung mit ein, weswegen daher ein massiver Ausbau auch jetzt geplant wird (Expert 4, 06/17/21).

"Leinpfad is a bicycle street along the Außenalster that is very busy and will be part of an ITS Tour. […] The data is used for traffic planning, which is why a massive is also planned now." (Own translation from German quote above).

Expert 3 mentioned the start-up FixMyBerlin. FixMyBerlin makes bicycle infrastructure planning visible and understandable for the public. The project aims to improve the communication between the city administration and the citizen. Acceptance of bicycle infrastructure projects and the quality and speed of realisation should be improved. The project is twofold, it shows what projects are in the planning phase and what is already finished, and it lets citizens express their opinion on where

bicycle stands or other bicycle infrastructure-related improvements are needed (BMVI, n.d.). Expert 3 stressed that the acceptancy between the cities' boroughs (Bezirke) is not equal. In some boroughs, a city employee physically checks where more bicycle stands are needed instead of using the digital solution. She also said that the previously mentioned app from Bike Citizens can give insights into cyclist behaviour and is therefore helpful for urban planners.

In general, expert 3 thinks that data gives many opportunities to direct bicycle traffic flows and avoid accident blackspots. However, she claims that data collection is not a perfect tool for bicycle infrastructure planning because the current amounts of cyclists does not say everything about the demand for bicycle infrastructure. To back up her argument, she quotes Brent Toderian:

"Es wäre, als ob man nur eine Brücke bauen muss, wenn genug Leute durch den Fluss schwimmen." (Expert 3, 06/11/2021).

"It is like you only have to build a bridge when enough people swim through the river." (Own translation from the original German quote above).

Expert 3 concluded by saying that bicycle data is a functional tool for planning new bicycle infrastructure; however, most important is a societal and political will to erect new bicycle infrastructure, independent from current bicycle usage.

Improving safety and reliability

The element of safety as an advantage for Smart Velomobility was mentioned in all five interviews.

Jorna referred to the Bicycle Pyramid developed by the Interreg project BITS (chapter 2.1.3.). He said that safety is the first thing that should be satisfied when different Smart Velomobility applications are considered.

"[Welke soort Smart Velomobility maatregelen je doorvoerd is] afhankelijk van op welk niveau van fietsinfrastructuur je zit. Ik kan me voorstellen dat je, als je een basisinfrastructuur niet goed op orde is, dat je meer wilt doen aan veiligheid. Heb je dat goed op orde, dan wil je naar het volgende niveau gaan" (Jorna, 06/06/2021).

"[Which type of Smart Velomobility applications you implement] depends on which level of bicycle infrastructure you are. I can imagine that when your infrastructure is not sufficient, that you first want to implement more safety measures. When that is all right, you may go to the next level." (Own translation from the original Dutch quote above).

For both city employees, expert 2 and expert 4, Smart Velomobility plays an essential role in implementing ITS projects. Expert 2 said that many possible Smart Velomobility measures can be used to improve safety for cyclists. Both mention the Smart Lamp Posts project that only lights up when someone passes by. Expert 2 stated that the advantage of this project is that it can reduce energy consumption. Furthermore, it can be especially beneficial for social- and traffic safety for bike paths through the city's parks that should not be lighted 24/7 to protect wildlife, as stressed by expert 4.

Another vital city intervention is that all city trucks must be equipped with blind spot warning systems to prevent tragic accidents with pedestrians or cyclists, according to expert 4. This is also backed up by expert 5, who said that cycling is currently mainly for the more adventurous people. Intelligent applications should make every cyclist comfortable. He claimed that it impossible to make every junction safer in a short timespan through physical infrastructure. By using technology safety can be improved more quickly. Expert 3, also acknowledged that technology can help making cycling safer; however, she believed that it is essential that the cities quickly improve their physical bicycle infrastructure too.

Digitalisation to improve multi-modal trips - Improving speed and convenience

The code *digitalisation to improve multi-modal trips* was used a total of eight times for four out of five interviews.

Several interviewees mentioned that Smart Velomobility can be used to make cycling part of a multi-modal trip. Ronald Jorna observed that multi-modality in the Netherlands is already quite good due to high-quality bike parking facilities at public transport stations. Outside of the Netherlands, this highly differs per region. He stressed that multi-modality can have a massive benefit for Co2 reduction.

"De potentie om Co2 te besparen, is met de fiets best wel weinig, omdat het vaak om korte afstanden gaat, dat zou misschien ook voor Hamburg iets kunnen zijn dat je zegt van ja, maar als we die fiets koppelen aan het openbaar vervoer en je kunt dus een combinatie van fietsen en OV gebruiken om een autorit te vervangen, dan is de Co2 winst wel heel groot." (Jorna, 06/06/2021).

"The potential to reduce Co2 emission with the bicycle is rather low because they are usually used for short distances. For Hamburg, however, it could be an option to improve the connection between the bicycle and public transport. The combination of public transport and the bicycle has a higher potential to replace a car trip, which would reduce Co2 emission considerably." (Own translation from the original Dutch quote above).

Jorna further expected that in the future, it will be possible to travel with one app with public transport, the bicycle, and other forms of mobility (MaaS). MaaS is also an essential objective for the ITS Hamburg strategy, as stress by expert 2 and 4. Expert addiontionalyy stressed that the current shared bike system (Stadtrad) will play an important role in MaaS solutions.

"Man kann ja auch darüber nachdenken, [die Leute die Multimodal reisen wollen] dann irgendwie die Hilfestellung zu geben. Ja, am besten Sie fahren mit Ihrem Fahrrad jetzt zu dem S-Bahnhof XY. Da schließen Sie das an, weil das ein schönes Fahrrad Parkhaus ist. Dann steigen Sie in die Bahn, die kommt auch sofort. Und dann kommen Sie am S-Bahnhof Z dann raus. Und da stehen übrigens auch Stadträder für Sie parat und Sie müssen nur hier tippen, wenn Sie das ausleihen wollen" (Expert 2, 06/04/2021).

"One could also think about helping [the people that want to make multi-modal trips]. Preferably you take your bicycle to the train station XY. There you can park your bicycle in the nice parking garage. Then you take a train for which you do not have to wait. Arriving at train station Z, you can take one of the city bikes that can be hired with the push of a button." (Own translation from the original German quote above).

This MaaS element will also play an essential role for the ITS 2021 Congress in Hamburg according to expert 4. There will be tours with different modes of transport through the city. Visitors can then compare how long public transport, the car, and the private and shared bicycle or a combination of modes take for a particular inner-city trip Expert 5 brought in a new perspective that the HEAT Shuttle in Hamburg can also support cycling.

"Pedelecs haben einen schlechten einfluss auf ÖPNV. Pendler nehmen bei schonem Wetter das Pedelec. Bei schlechtem fahren sie Bus. Wenn Busse nur bei schlechtem Wetter ausgelastet sind rechnet es sich nicht. Die HEAT Shuttle ermöglicht neue Multi Modale Transportmöglichkeiten. Shuttles können flexibel eingesetzt werden. Wenn sie automatisiert fahren, kostet das stehen nicht. Es muss kein Fahrer bezahlt werden." (Expert 5, 06/18/2021).

"Pedelecs have a bad influence on public transport. When the weather is nice, people take the pedelec. In bad weather, they take the bus. However, when busses are only used a lot in bad weather conditions, they do not pay off. The HEAT Shuttle allows for new multi-modal trips. Shuttles can be deployed flexibly. When they travel autonomously, having them not in use does not cost anything. No driver has to be paid. (Own translation from the original German quote above).

Expert 5 explains that with such autonomous shuttles, cyclists are offered a water-resistant alternative. This makes a bicycle commute more attractive. The autonomous shuttle can therefore support Smart Velomobility and should not be seen as a holdback.

Further advantages of Smart Velomobility

Expert 4 further mentioned the opportunities to promote cycling by offering bonuses for people who cycle with an app. An example of this is the DB RAD+ App that promotes bicycle use to the train station (not part of the anchor projects). Jorna further mentioned the gamification aspect of some Smart Velomobility projects. Smart Velomobility allows people to have more fun when cycling by offering them interesting new routes. This adds value next to the most essential element of the bicycle pyramid.

Ideal Smart Velomobility

Bicycle experts Jorna and expert 3 mentioned some elements an ideal Smart Velomobility project should meet (table 6).

	1: Interview 3 26	5: Interview 1 34	Totals
SV: Ideal: added value 1	1		1
SV: Ideal: fixed infrastructure versus app 1		1	1
SV: Ideal: follow pyramid 1		1	1
SV: Ideal: intelligent is not necessarily digital 1	1		1
SV: Ideal: open data for other developers 1		1	1
Totals	2	3	5

Table 6 Ideal Smart Velomobility.

According to Jorna, it must be balanced whether fixed sensors should be built for communication with traffic lights or if this should be done through apps. The advantage of using apps is that it is easier to implement projects on a city scale, however it can be questioned if people actually still want to use an app after the few times, they tried it out of interest.

Important for Jorna is further to publish all data collected in an open portal and make this data accessible for app makers. This allows app makers to make even more intelligent solutions for the bicycle.

For expert 3, intelligent solutions are not necessarily digital. She said that planenrs should improve our cities in collaboration between different people in a human-centred way. Moreover, Smart Velomobility measures that are implemented should have an added value.

"Zum Beispiel eine App für Routenplanung. Das ist ein unglaublicher Mehrwert und das ist ja auch für eine breite Masse wichtig." (Expert 3, 06/11/2021).

"For example, an app for route planning. That has a huge added value and is important for the general public." (Own translation from German quote above).

4.2.2. Disadvantages of Smart Velomobility

All interview partners were asked about potential disadvantages of Smart Velomobility. As visualised in the code-document table below, experts 4 and 5 did not mention any disadvantages. Most disadvantages were only mentioned once (table 7).

	1: Interview 3 (26)	2: Interview 4 (51)	3: Interview 5 (18)	4: Interview 2 (44)	5: Interview 1 (33)	Totals
SV: Disadvantage: can result in unsafe usage (1)					1	1
SV: Disadvantage: citizens worry about privacy (2)				1	1	2
SV: Disadvantage: exclude some users (1)					1	1
SV: Disadvantage: lock-in (2)	2					2
SV: Disadvantage: marginal business compared to automative industry (1)					1	1
SV: Disadvantage: may conflict with existing regulations (1)				1		1
SV: Disadvantage: too technological (3)	2			1		3
Totals	4	0	0	3	4	11

Table 7 Disadvantages of Smart Velomobility

Too technological

The code *too technological*, was used two times for interview with expert 3 and once for the interview with expert 2.

Expert 2, mentioned as a potential disadvantage of Smart Velomobility, the problems that may occur because of the novelty of the applications. As an example, he referred to the Smart Lampposts that were described before (chapter 4.2.1. - Improving safety and reliability). Citizens might be disturbed when lights go on and off regularly. Also, current regulations may have to be changed because they do not foresee such a technique. Concerning Smart Velomobility for the bicycle itself, expert 3 worried that such technologies would hinder the bicycle's simplicity and increase the ecological impact of the bicycle.

"Was ich z.B. im Radverkehr als kritisch wahrnehme ist wie Fahrräder mittlerweile aussehen und wie Hochtechnologisiert Fahrräder werden. Also wie man wegkommt von so einem einfachen Omafiets zu einem E-Mountainbike, was 5.000 Euro kostet. Das sind einfach aufgeblasene Maschinen. Und wir müssen schon aufpassen, dass wir mit dieser Elektrifizierung und auch die Digitalisierung ein gewisses Maß halten, auch in Bezug auf Klimaschutz." (Expert 3, 06/11/2021).

"What I critize in the development of bicycles is how highly technological bicycles get, how the bicycle developed from a simple granny bike to an e-mountain bike costing 5,000 euros. Those are just pompous machines. Moreover, we have to be careful that we stay moderate in this electrification and digitalisation process and consider climate protection. (Own translation from the German quote above).

Expert 3 also worried that the bicycle trend goes to an overengineering of the bicycle digital solutions that aim to make cycling safer like smart helmets and other gear, putting the cyclist in a victim role. Furthermore, she warned of a lock-in situation with technology dependency.

"Wir müssen auch wahnsinnig aufpassen, dass man die Städte jetzt nicht auf diese autonom fahrenden oder elektrisch fahrenden Fahrzeuge ausrichtet. Ein Elektrofahrzeug braucht genauso viel Platz wie ein herkömmliches Fahrzeug. Und da brauchen wir halt einen disruptiven Ansatz, die Städte anders zu denken in Bezug auf Aufenthaltsqualität und in Bezug auf Verkehrssicherheit." (Expert 3, 06/11/2021).

"We have to take care that we do not plan our cities for these autonomous- or electric vehicles. An electric car needs the same amount of space as a regular car. We need a disruptive approach to rethink cities in terms of liveability and traffic safety." (Own translation from the German quote above).

Privacy

Both Jorna and expert 2 referred to potential privacy issues as one of the risks for Smart Velomobility. To mitigate this risk, expert 1 advised to build in guarantees that personal data will never come into the wrong hands. This can be done by anonymising the data directly in the data collection process, for example, by using heat sensor cameras instead of visual cameras. Also, in Hamburg, expert 2 mentioned that he has received letters from citizens worried about what happens with their data. Therefore, the city should always be transparent about collecting data to not suffer from citizen backlash.

Exclusion of users

As a potential risk for Smart Velomobility applications, Jorna compared the Smart Velomobility applications with the Corona Warning Application[4]. Users of older smartphones complained that they could not use the app. Smart Velomobility applications can be problematic when some people cannot use them because their smartphones are too old or because the users do not know how to operate the devices.

Unsafe usage

Jorna, also mentioned that people might use applications on the bicycle in a dangerous manner. For example, by holding the phone in their hands or focussing too much on their screen while in traffic.

Smart Velomobility as a marginal business

Compared to the automotive industry, Smart Velomobility is a marginalised business. Only in recent years Smart Velomobility projects came into play, according to Jorna. He thinks this mainly has to do with the lower budget of the bicycle manufacturers and the omnipresent risk of theft.

"Dus de fiets zelf kun je moeilijk slimmer maken, je kan het vooral er omheen slimmer maken." (Jorna, 06/06/2021).

"So making the bicycle itself smarter is difficult, you can mainly make the environment around it smarter." (Own translation from Dutch quote above).

[4] The Corona Warning App is a Bluetooth application that warns the users when he or she was in close vicinity with someone who tested positive for Covid-19.

4.2.3. Role Smart Velomobility for the Mobility transition

Interviewees were asked what their estimation was about the role Smart Velomobility plays in the mobility transition of Hamburg and their general estimations of the mobility transition Hamburg (table 8).

	1: Interview 3 (26)	2: Interview 4 (51)	3: Interview 5 (18)	4: Interview 2 (43)	5: Interview 1 (34)	Totals
MT: also offer service on the edge of the city (1)		1				1
MT: better PT, last mile support PT (2)		2				2
MT: discourse unbalance (2)	1			1		2
MT: hindrance: lack of cooperation (3)	1		2			3
MT: hindrance: no sufficient change (1)	1					1
MT: hindrance: people are too convenient (1)	1					1
MT: political climate changed (11)		2	1	6	2	11
MT: some ITS project are needed for the MT (1)		1				1
MT: technology can help but is not an alternative for safe infra (6)	3	3				6
Totals	7	9	3	7	2	28

Table 8 Role of Smart Velomobility for the Mobility Transition.

Changed political climate

The changed political climate was mentioned in four out of five interviewees. As a project leader at the EU Interreg project BITS, Jorna stated that mobility data becomes more important on the EU scale. Also, in the context of the Green Deal,[5] the EU is investing more in the bicycle. The bicycle is one of the greenest modes of transport. However, fundings for the bicycle are still relatively low because people usually do not cycle more than 7,5 kilometres per trip on a regular bike and 15 km on an e-bike. New opportunities of multi-modality (MaaS) partly make up for this disadvantage of the bicycle (see also chapter 4.2.1 - Digitalisation to improve multi-modal trips - Improving speed and convenience). He also observed that cities in EU member states focus more on the bicycle in, for example, SUMPs. This effect was further accelerated due to the COVID-19 pandemic.

Expert 2, 4 and 5 all stated that the political climate changed in Hamburg since the city council got a new traffic senator from the Green Party, Tjarks, an avid cyclist himself. According to expert 2, this allows for more drastic measures to stimulate cycling. In 2020, the traffic authority was newly founded from Behörde für Wirtschaft und Innovation (Authority for Business and Innovation) to an independent traffic authority called Behörde für Verkehr und Mobilitätswende (Authority for Traffic and Mobility Transition).

"Der politische Wind hat sich ein bisschen gedreht und man hat dann halt immer so gewisse Leitlinien und Ziele und jetzt ist halt das große Ziel, die Mobilitätswende herbeizuführen." (Expert 2, 06/04/2021).

„The political climate has changed a bit. There are always specific guidelines and objectives we follow, and now the significant objective is to bring about the mobility transition." (Own translation from German quote above).

Expert 2, however, repeated that this does not mean that the bicycle was not significant before in Hamburgs' traffic strategy. The Hamburg bicycle counting system (HaRaZäN) was for example, first requested in 2017, long before the new traffic authority came into play. For him, the bicycle has a vast potential that is far from exhausted in Hamburg.

[5] The Green Deal is a set of policy initiatives by the European Commission, with the overaching aim of reducing greenhouse gases to 0 by 2050 and becoming the first climate neutral continent (European Commission (n.d.).

Moreover, expert 4 said that cyclists should be prioritised at crossings at which cyclists outnumber the number of cars, HGV, and busses in the future. Currently, the motorised traffic standard has a green light on junctions. Only the traffic light has detected the cyclist through a sensor in the road or with the push of a button, the cyclist will get green. In the future, cyclists should get green by default on such crossings. Measures like this are always expected to have backfire from opposing groups. However, he expected that with the green party's traffic senator, such changes are likely to happen in the future.

Expert 4 further continued by stating that the City of Hamburg takes a significant share in ITS projects that should make sustainable modes of traffic like cycling and public transport more attractive. These projects are an essential element of reaching the mobility transition objectives of the city.

According to expert 5 the, ITS strategy was developed before the political climate changed in Hamburg. Therefore, the ITS strategy is a heritage for Tjarks. Both strategies must function parallelly. This sometimes can result in clashing conflicts, to make cycling safer on a street, a pop-up bike lane was planned. However, this street was also part of the track for autonomous vehicles in the city centre of Hamburg. Therefore, it was not possible to implement the pop-up bike lane on this location.

Discourse unbalance

Expert 3 stated that there is a strong discourse unbalance in the debate of autonomous vehicles and the electrification of motorised vehicles on the one hand and pedestrians and cyclists on the other. Expert 2 did not explicitly mention discourse unbalance, but he explained about messages the traffic authority becomes from cyclists that the growing group of cyclists must wait too long at the traffic light. This indicates that Hamburg's bicycle infrastructure is not always keeping up with demand.

Offer service on the edge of the city

For expert 4, it is crucial also to offer services like shared vehicles on the edge of the city, because these people are most likely to travel by car. This allows for using the bicycle or E-Scooter as the first and last mile mode of transport for public transport users.

ITS projects are needed for the mobility transition

According to expert 4, many ITS projects like aVME and Geonet Beacon (chapter 4.1.) are supported by the local government because they are needed to reach the mobility transition objectives.

Technology is not an alternative for physical infrastructure

For expert 3, the most important element needed for a mobility transition is the redesigning of streets. In her opinion, streets should be designed to give pedestrians, cyclists, and public transport more space.

"Wir müssen Platz umverteilen und die [Stadt]straßen nicht mehr von innen nach außen entwicklen. Also erst das Auto und dann guckt man mal was übrig bleibt sondern erst den Fußverkehr dann Radverkehr und dann öffentlicher Verkehr." (Expert 3, 06/11/2021).

We have to redistribute [city] streets and should no longer design them from the inside in. So first the car and then you look what is left, but first pedestrians, then cyclists, and then public transport." (Own translation from German quote above).

Expert 4 elaborated on the lack of separation between bicycle infrastructure on some main city streets. Often motorised traffic uses the bicycle lanes to park or drive on.

"ITS kann nur einen kleinen Beitrag leisten, den Radverkehr zu verbessern weil digitale Angebote die Infrastrukturmaßnahmen nicht ersetzen können." (Expert 4, 06/17/21).

"ITS can only make a small contribution in improving bicycle infrastructure because digital services cannot substitute [physical] infrastructure measures."(Own translation from German quote above).

Mobility transition hindrance

As a hindrance to the mobility transition, both expert 3 and 5 mentioned the lack of cooperation between stakeholders. Expert 5, criticized the lack of understanding between activists that are rather anti-car than pro bike in his opinion. He thinks that this results in unnecessary conflicts between different interests' groups. The ITS Hamburg strategy solves this better, in his opinion.

"Die ITS Strategie zeigt was menschen annehmen können. Verbote bringen uns nicht weiter. Dann gehen menschen in die Opposition." (Expert 5, 06/18/2021).

"The ITS Strategy show what possibilities people have. Prohibitions do not help us further. That only leads to people going into resistance." (Own translation from German quote above).

For expert 3, the main issue is the lack of cooperation between stakeholders because people 'speak different languages' and do not understand each other's desires. Also, the change in German cities is not disruptive enough for a mobility transition and people are often too convenient. She, therefore, is afraid of the effects of autonomous cars on people's mobility choices.

"Der Großteil der Menschen ist wahnsinnig bequem und deswegen muss man Anreize schaffen um aktiv zu bleiben, dass man zu Fuß irgendwo hingehen kann oder mit dem Fahrrad und nicht dafür in ein Auto steigen muss. Das Horror-Szenario ist eben auch, dass irgendwie jedes Kind auf dem Weg zum Fußballtraining sich ein autonomes Auto ruft, anstatt eigenständig dorthin zu laufen oder mit dem Fahrrad zu fahren." (Expert 3, 06/11/2021).

"Most people are insanely convenient, therefore, it is needed to create incentives to stay active and create the possibility that people can just walk anywhere or take a bike without the need for a car. The horror scenario would be that every child on its way to football training calls an autonomous car, instead of walking or cycling there on their own." (Own translation from German quote above).

4.2.4. ITS Hamburg objectives

Experts 2, 4, and 5 were asked which objectives the ITS Hamburg strategy should follow. Jorna and expert 3, are not directly involved in the Hamburg ITS strategy and therefore were not asked this question (table 9).

	2: Interview 4 (51)	3: Interview 5 (18)	4: Interview 2 (43)	Totals
ITS objectives: also less tech savvy people should profit (3)			3	3
ITS objectives: citizens are involved (6)	5		1	6
ITS objectives: city marketing (2)	1	1		2
ITS objectives: city must become smarter (1)			1	1
ITS objectives: cleaner air (1)		1		1
ITS objectives: less cars (1)		1		1
ITS objectives: more efficient mobility (1)		1		1
ITS objectives: reach goals through cooperation (1)			1	1
ITS objectives: showcase to visitors (5)	3	2		5
ITS objectives: try out new things (1)			1	1
Totals	9	6	7	22

Table 9 ITS Hamburg objectives.

Involve citizens and visitors

Both expert 2 and 5 mentioned the importance of involving citizens. In the end, the citizen and visitors of Hamburg should profit from ITS projects. A public day is organised to facilitate citizens that want to learn more about the projects. Citizens from Hamburg can visit the congress for free.

However, not only during the congress, citizens are involved. Expert 4 stressed that lot of information is published on different social media channels and the ITS Hamburg website.[6] Furthermore, citizens and visitors can directly make use of future initiatives like the digital S-Bahn (commuter train) to Bergedorf.

Additionally, the city marketing aspect of the ITS Congress is important:

"Der Kongres bringt die stadt Geld. Für die Hotels und Gassttätte ist es von Vorteil. Das Kongress bietet ein Schaufenster für neue Technologien. Hamburg kann ihre ITS Strategie Unterstreichen. " (Expert 5, 06/18/2021).

"The city profits from the congress. It benefits hotels and restaurants. The congress provides a showcase for new technologies. Hamburg can emphasize its ITS strategy." (Own translation from German quote above).

Expert 4 also stressed the importance of Hamburg's image for business and tourism. In recent years surveys have shown that Hamburg's mobility is perceived more positively than in the past.

Other ITS objectives

Expert 2 emphasised that also people that are less tech-savvy should profit from Smart Velomobility. Thanks to the e-bike trend, especially older or vulnerable people cycle more. This group would significantly benefit from safety improvements through digital tools. Furthermore, he believed that our cities need to become more innovative. To reach this goal, it is crucial to collaborate with other cities and learn from experts. The PMO coordinates current and potential projects. Also, offers from different commercial parties are evaluated by this organisation. Hamburg is open to trying out new experimental techniques such as heat sensors instead of cameras for traffic counting.

Expert 5 said that the city could get cleaner air through ITS measures by offering alternatives for the private car. ITS can make alternative modes of transport more attractive compared to the private car. To back up his argument, he mentioned the autonomous HEAT Shuttle that is currently tested in Hamburg and MaaS applications. ITS can also benefit cyclists by making it a safer and weatherproof alternative (See chapter 4.2.1. Digitalisation to improve multi-modal trips - Improving speed and convenience).

[6] https://www.hamburg.de/its/

4.2.5. Prioritizing between different interests

As explained in the introduction, many scholars criticize the lack of priority for cyclists in Smart City strategies. Also, fears for the marginalisation of citizens exist. Both city employees expert 2 and expert 4 were asked how different priorities between modes of transport are decided, and to what extent citizens can participate (table 10).

	2: Interview 4 60	4: Interview 2 45	Totals
Priorities: amount of bicycle projects 1	1		1
Priorities: budget 2	2		2
Priorities: citizen participation 2	1	1	2
Priorities: cooperating with automative industry 2	2		2
Priorities: decision making 2	2		2
Priorities: inform the general public 2	1	1	2
Priorities: its the money of the citizens 1		1	1
Totals	9	3	12

Table 10 Prioritizing between different interests

Information and participating citizens

Both expert 2 and 4 mentioned the importance of informing citizens and visitors of the city about the ITS activities. The city informs through press conferences, press releases, social media channels and their website.[7] Expert 2 stresses the importance of informing the citizens.

"Das ja auch deren Geld was wir da nutzen und daher sollen die Wünsche [der BürgerInnen] berücksichtigt werden. Das ist sowie das Ziel von diesen [ITS] Projekten."(Expert 2, 06/04/2021).

"That is their money what we use, and therefore we should consider the wishes [of the citizens]. That is definitely the objective of these [ITS] Projects." (Own translation from German quote above).

According to expert 4, there was no direct citizen participation for the ITS strategy apart from informing. However, for individual ITS projects, there has been citizen participation. Expert 2 gave the example of the location for the shared bike stations (Stadtrad). In a public participation round, users were asked where the new Stadtrad stations should be built. The same goes for the traffic development plan (Verkehrsentwicklungsplan) in which citizens could play a game in which they were asked for what measures they would spend their money.[8] Part of this game are also ITS and Smart Velomobility measures. Furthermore, the individual boroughs (Bezirke) stand closer to the people and participate in new urban planning.

Decision making

Expert 4, explained the four structures of the ITS program management. An explanation can be found in chapter 2.2.1. He also stated that projects can have different origins. City authorities directly initiate some projects, and other projects are started in partners' responsibility like commercial

[7] https://www.hamburg.de/its/

[8] https://vep-hh.urbanista.de/urbanista_szenariospiel/

parties or knowledge institutes. The PMO manages the ITS dashboard (chapter 2.2.1.). This dashboard allows to filter ITS projects for their status (planned, finished or ongoing) and their relevance for different modes of transport. Out of the 201 ITS projects in Hamburg, 48 have something to do with cycling and are thus Smart Velomobility projects.

Budget

For ITS Hamburg there is no separate budget according to expert 4. The PMO monitors the individual ITS projects but is not responsible for the budget. Projects are either financed by the local government, the federal government or a wide variety of institutions and organisation. Projects can also be financed by different partner simultaneously. It, therefore cannot be easily said how much budget is used for bicycle-related projects and projects for other modes of transport.

Cooperating with the automotive industry

It may sound counterintuitive to cooperate with the automotive industry when the objective is to reduce emissions and have less cars in the city. But, as stated by expert 4, no partner should be left out in advance to bring about the mobility transition.

"Wir kooperieren im ITS-Bereich dann auch mit der Autoindustrie, die Technologien anbietet, so wie Volkswagen das mit Moia z.B. macht, die auch dazu beitragen sollen, den Individualverkehr zu reduzieren"(Expert 4, 06/17/21).

"We also cooperate with the automative industry in the ITS area, because they offer technologies that should reduce private vehicle usage like for example MOIA from Volkswagen." (Own translation from German quote above).

5. Conclusion

5.1. Main research question

Even though the mobility transition objectives and ITS strategy were developed in a different political climate, both strategies show overlapping objectives as described in the introduction. Therefore, this thesis answers the following main research question:

MRQ. To what extent can Smart Velomobility contribute to Hamburg's wanted traffic transition?

The why, how, and what

Smart Velomobility can benefit current and potential cyclists in many ways (see SRQ3). For many potential cyclists', safety, and comfort are concerns that keep them away from cycling (more) (Dill & McNeil, 2013; Francke & Lissner, 2021).

Through technology, safety can be increased more quickly than it would have been possible with just physical infrastructure improvements (expert 5, 06/18/2021). Digital solutions are not an alternative for physical infrastructure upgrades (expert 3, 06/11/2021; expert 4, 06/17/2021). Hamburg still has much work to do to bring about the bicycle mobility transition (see chapter 2.2.4.).

One of the essential benefits of Smart Velomobility is MaaS. Because Hamburg is a big city, distances are often also long. Thanks to MaaS, people can integrate cycling more efficiently in their daily trips (Jorna, 06/06/2021; expert 2, 06/04/2021; expert 4, 06/17/2021). Currently the shared bike system is not yet integrated into Hamburg's MaaS App (HVV Switch) (Hamburger Hochbahn AG, n.d.; Hansestadt Hamburg, 2021b). When this option is added, the Smart Velomobility contribution to Hamburg's traffic transition would be considerable.

Hindrance of Smart City

A potential hindrance for future Smart Velomobility is that autonomous driving becomes too convenient compared to cycling. Furthermore, cyclists may have to deal with more danger in the transition phase towards autonomous cars (Botello et al., 2019). Therefore, incentives should be developed to prevent people from just taking an autonomous car when that becomes an option (expert 3, 06/11/2021). Further research is needed on whether these incentives should be monetary or of a different nature.

Investments in line with other modes of transport

Because a wide variety of partners finances the ITS Hamburg projects, it was impossible to compare investments in Smart Velomobility vs investments in other ITS measures. To ensure that Smart Velomobility maintains a proper element of Hamburg's ITS strategy it can be thought about a minimum percentage of Smart Velomobility in the overall ITS Hamburg budget. Further research is needed on whether this can be done with the many different stakeholders and how high this budget should be.

5.2. Sub research questions

Several sub research questions help with answering the main research question:

SRQ1. To what extent is Smart Velomobility considered in Hamburg's ITS strategy?

Outcomes compared to the theory

As explained before, Behrendt (2019) criticized that Smart Velomobility is not considered much in Smart City or IoT strategies. To test this theory, a case study was conducted. Through triangulation (literature review, policy analysis and expert interviews), it was researched whether this is also the case in Hamburg. Opposed to existing literature, Smart Velomobility is a topic that is considered in Hamburg's ITS strategy.

The PMO Dashboard shows an overview of all ITS projects in Hamburg and the surrounding region. Out of the 201 ITS projects in Hamburg (12th of August 2021), 48 have something to do with Smart Velomobility (PMO, n.d.) The 42 anchor projects[9] were analysed more in-depth (see chapter 4.1.). Analysis showed that fifteen projects have at least relevance for cycling. Of those fifteen, two are fully cycling related (PrioBike-HH & HaRaZän). In ten further projects, several modes of transport are considered, of which the bicycle is one. An example of such a project is GeoNetBeacon. This project is a system of traffic beacons with sensors that shares live information about construction sites with the Urban Data Hub. This is beneficial as cyclists must often deal with unannounced road works in Hamburg (expert 4, 06/17/2021).

There are also three further projects that either consider cyclists (TIQ, HEAT and TAVF) or offer an additional benefit for them (HEAT). As expert 5 stated, the HEAT shuttle can function perfectly next to pedelecs on the city's edges. In these areas, public transport tends to be less good compared to the centre of the city. With electric supported bicycles, people can travel further distances, as also stated by Jorna. However, when the weather is not optimal for cycling, people may prefer a weatherproof alternative. The HEAT shuttle can be deployed more easily because it would not need to have a driver and can thus still be financially feasible even though they are only fully occupied in bad weather. Therefore, the HEAT shuttle can benefit cyclists because it offers a rainproof alternative for people who want to cycle further distances.

[9] The ITS Hamburg strategy has 42 flagship projects (Anchor projects). projects) these projects particularly important to reach the ITS Hamburg objectives and are a source of inspiration for the other ITS projects.

Most ITS projects are not cycling related, and many Smart Velomobility projects are still in the testing phase. Some of those projects will first be shown at the ITS Congress in October 2021. Other projects are due until 2030. The current Hamburg situation would, therefore, not be regarded as a matured Smart Velomobility city. However, with the efforts the city makes in respect to Smart Velomobility the city seems to be on a good way.

SRQ2. How are the priorities in the ITS measures of Hamburg decided? How do different powers relate?

Initiation of ITS strategy

The ITS strategy was initiated by the city council of Hamburg in 2016 to improve the cities' liveability and economic development. There are preliminary milestones for the ITS Congress in 2021 and objectives for 2030. As explained by expert 4, there are different parties that initiate different ITS Hamburg projects. Some are directly initiated by the city's authorities, while others come from external parties like knowledge institutes and companies (Hansestadt Hamburg, 2016, 2018a). A variety of stakeholders contribute to make this happen. An explanation about the different parties involved can be found in chapter 2.2.

Political climate changes

Both a change in political climate on the EU scale (Jorna, 06/06/2021) as well as in Hamburg were mentioned. Expert 2, 4, and 5 mentioned the new traffic Senator, Tjarks as a frontrunner to integrate more cycling friendly strategies. Both in regularly traffic planning and within the ITS strategy. This however, does not mean that Smart Velomobility was not an issue before Tjarks was installed (expert 2, 06/04/2021).

Citizen participation

The city employees expressed the importance of involving the citizens. Citizens are informed through a variety of channels. However there has not been a citizen participation process for the ITS strategy. Nevertheless, mainly projects from the ITS strategy have seen some sort of citizen participation. A good example of this is the traffic development plan for which extensive citizen participation took place.

SRQ3. What are the opportunities for Smart Velomobility in Hamburg? Which Smart Velomobility measures should be taken in Hamburg? For which target groups?

Advantages

Smart Velomobility can have several advantages. First of all, data can be given directly back to the end-user. Hamburg already is working on it with projects like the PrioBike-HH project. Another element is that urban planners can use more detailed data to plan better bicycle infrastructure of which cyclists also profit. In addition to this, Smart Velomobility has the benefit to integrate cycling better in multi-modal trips (e.g., HVV Switch App). This increases the value cycling can have to save emissions as stated by interview partner Jorna.

Implement the bicycle pyramid to the local context

The interview partners confirmed the theory from the BITS project that cycling can be made safer, quicker, and more comfortable through Smart Velomobility measures. Expert 5 stated that Smart Velomobility allows to improve safety at crossings much faster than physical measures could do. Nevertheless expert 3 and 4 stressed that physical infrastructure measures are still needed to improve safety and comfort of cyclists in Hamburg. Cycling in Hamburg is compared to cycling cities in the Netherlands and Denmark relatively dangerous (Pucher & Buehler, 2008). Hamburg and other cities with sub optimal cycling conditions should therefore primarily focus on project that increase safety. Projects that should increase speed and comfort can additionally improve the quality of

cycling. These projects, however, should be prioritised less (Interreg North Sea Region, n.d. & expert 2, 06/04/2021).

Learn from the best

The Smart Velomobility Index in this thesis offered some advice on which projects are more relevant for cycling. Planners and politicians in Hamburg will benefit from this analysis. Stakeholders from other cities may use it as an inspiration, the transferability to their local context might however be low. Furthermore, Hamburg should stay in close cooperation with other cities that implement Smart Velomobility measures to ensure cross-border learning. It is not necessarily an issue when projects do not improve Smart Velomobility.

HVV Switch

The HVV Switch App is a good foundation for a city wide MaaS application. However, the fact that the shared bike system (Stadtrad) is not integrated into the app is a missed opportunity. Integrating the bicycles into HVV Switch would be a quick win for Hamburg's Smart Velomobility.

Not a one size fits all solutions

Smart Velomobility is however, not a one size fits all solutions. As explained before, cyclists are not a homogenous group. It should be therefore researched which interests different target groups may have. The image below shows a first sketch of which elements of Smart Velomobility different people may value more (figure 18). The different groups are adapted from Dill & McNeil (2013), Francke & Lissner (2021) and Baltac (2019). On the one hand younger digital native target groups may value gimmicks and speed more than older users. On the other hand, those older people are likely to value safety more.

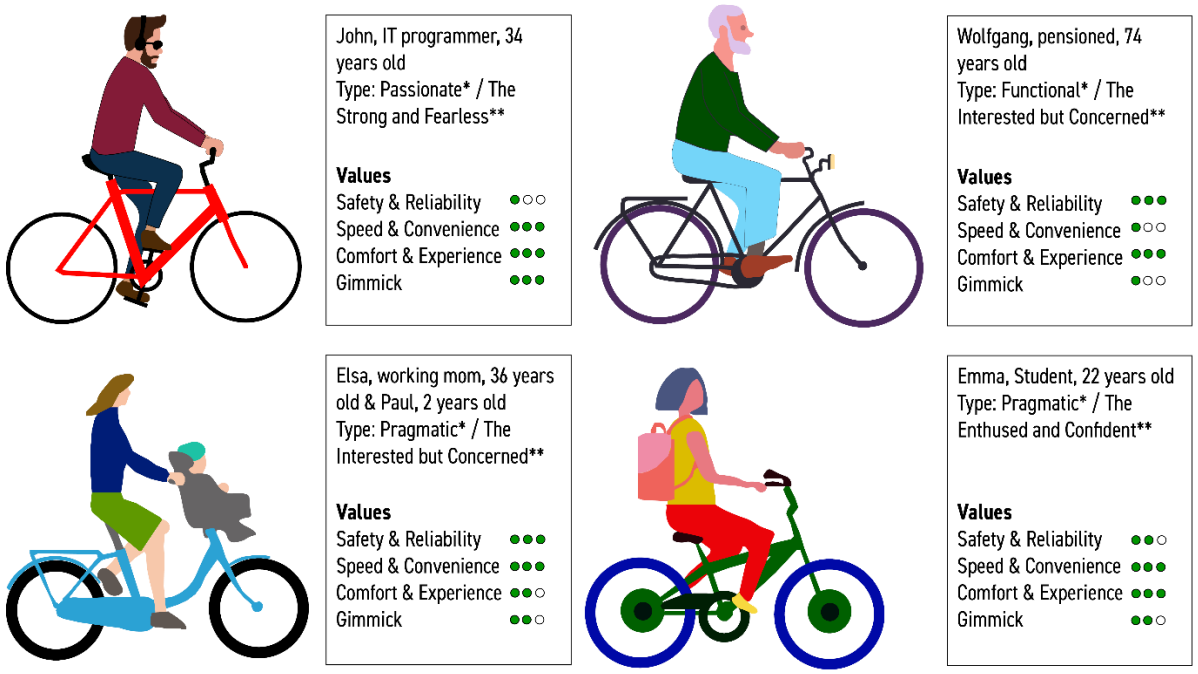

*Figure 18 First sketch of which Smart Velomobility elements different people may value more. Own image adapted from Dill & McNeil (2013)**, Francke & Lissner (2021)* and Baltac (2019).*

SRQ4. What are the disadvantages of Smart Velomobility in Hamburg?

Privacy issues

In the theoretical framework several disadvantages of Smart City and Smart Velomobility were mentioned. Because data is often needed for Smart City projects, fears of privacy violation may exist (Streitz, 2019). This was also mentioned by Jorna and expert 2. Jorna advises to guarantee that data cannot end in the wrong hands, which could be prevented by anonymising the data directly when it is collected. For city employee, expert 4, privacy is also an important topic. He said that it should always be transparent for the user what data is collected and what is done with that data.

Exclusion

A further disadvantage that was mentioned in the literature and the interviews is the potential exclusion of certain groups. McLaren et al. (2018), worry that Smart City strategies cause another division within a city's population. Lefevre (2014) is concerned that cities are misused by commercial business to earn money. He suggests that the city council must have a strong negotiation position to ensure that only projects are initiated of which local citizens profit.

Moreover, there is a potential risk that people who are not digital natives do not profit from Smart City initiatives due to the digital divide. Baltac (2019) developed a four-pillar strategy that should bridge this divide (chapter 2.1.2.). This exclusion of cyclists was also mentioned by interview partner Jorna who stated that some people may not be able to use certain mobile applications because their devices are too old.

Unsafe usage

Another potential disadvantage is that people are urged to use smart applications on their bicycle in an unsafe manner. They may concentrate too much on their screens or hold the phone in their hand while cycling (Jorna, 06/06/2021).

Problems due to novelty of the technology

Furthermore, problems due to novelty of the software may occur when regulations do not fit the new technology (Expert 2, 06/04/2021). An over technologicalisation of cycling can also be seen as a disadvantage of Smart Velomobility as addressed by expert 3. She expressed her concern about bicycles becoming more expensive, less ecological, and putting cyclists in the victim role.

6. Reflection

What went well?

From November 2020 on, I decided that I wanted to combine a thesis with an internship. Because I wanted to write about Smart City Hamburg, I applied for an internship at an office for urban planning and mobility research (Orange Edge) in Hamburg, specialising in Smart City. Working there gave me a better connection to planners practice and allowed me to join a group of students from the University of Kassel, that all worked on ITS topics. The regular meetings with the group gave me additional feedback from Professor Bremer, her assistant Raddatz, and the fellow students as an addition to the feedback from dr. Bahrami.

Being in the second pandemic year while writing a master's thesis went surprising well. All interview partners were cooperative to contribute to this research in online interviews. Expert 4 granted access to the PMO Dashboard, which is not publicly available, which was also a huge benefit for this thesis.

What did not go well, and what would you have done differently in hindsight?

I underestimated how difficult it would be to combine the writing of a thesis with doing a full-time internship. This resulted in getting a bit behind schedule. Ideally, I would have conducted more than the current five interviews. Due to time constraints, this was, however, not possible. In hindsight, I would either plan a shorter internship or an internship with less workload. Additionally, my time management could also have been better. Nevertheless, the internship was definitely worth the additional workload because I could learn a lot from planning practice in general and specifically for Hamburg next to the theoretical knowledge from the university.

Are the outcomes convincing to you?

In general, I am happy about the methods used and the outcomes of this research. The policy analysis and literature review supported the interviews and vice versa. I also believe that my personally developed Smart Velomobility Index contributed to the outcomes of this thesis. A remark could be made whether there should be a difference in valuation between completely cycling-related projects and projects that incorporate cycling. In hindsight, it is not evident that the latter type of project is less beneficial for cycling. Further researchers that want to use this method should rethink this element.

Furthermore, it would have been beneficial to have budget data for all ITS projects to make a fair comparison between modes of transport. However, this was not possible because there is a wide variety of project initiators and because such information is competition sensitive. For the same reasons, it was only looked in-depth into the 42 anchor projects out of over 200 ITS Hamburg projects.

Learning outcome and contribution to research

Because not much is known about the incorporation of Smart Velomobility in ITS or IoT strategies of individual cities, this research contributed to this field of research. The outcomes of the research of Behrendt (2019) could not be confirmed. Furthermore, the personally developed Smart Velomobility Index can be easily transferred to other contexts, e.g., a different city or region. With the developed method and in-depth research on Hamburg, the smartest big city in Germany, this case study allowed for a strong empirical foundation to generalise the outcomes (Yin, 2013).

Further research is needed to examine whether it is possible and beneficial to dedicate a specific budget for Smart Velomobility and how high it would need to be. Furthermore, the Smart Velomobility Index may be adapted to another local context. Moreover, it should be researched which types of Smart Velomobility projects are helpful for different target groups. With the image in chapter 5.2. (figure 18), I estimated, based on research by Dill & McNeil (2013), Francke & Lissner (2021) and Baltac (2019), what different people may prefer. However, more quantitative and qualitative research would be needed to give this a better scientific foundation.

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Declaration of Originality

I hereby declare that the work in this thesis was composed and originated by myself and has not been submitted for another degree or diploma at any university or institute.

I certify that all information sources and literature used are indicated in the text and a list of references is given in the reference list.

Hamburg, August 17, 2021

Tom Kloos

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Interview Guide

Opening

Thank for very much again for your willingness to participate in this research. As explained before by email I would like to interview you about the position that Smart Velomobility have within the ITS Hamburg strategy. With Smart Velomobility all Smart City measures that incorporate cycling are ment. Furthermore, I would like to understand what the value of Smart Velomobility can be for the Mobility Transition in Hamburg. The interview will take around 45 to 60 minutes.

Consent

I need to have your consent that you participate voluntarily in this interview and that you understand that the interview can be ended anytime. To make sure that you can answer as freely as possible I would suggest that I anonymise your answers. It would make the analysis of the results easier if I could record the interview. Would that be alright for you?

Warming up questions

Can you tell me a bit about yourself? What are your professional activities? How are you involved in ITS/ cycling?

How is this organisation structured?

General questions

What are the most important developments in ITS that come to your mind?

- In Europe;
- In Germany;
- In Hamburg.

What are main advantages of smart Velomobility in your opinion?

Are there disadvantages for Smart Velomobility in your opinion?

- Should it be technological?

Do you see further opportunities for Smart Velomobility in the future?

Hamburg wants to bring about the mobility transition. What do you think that ITS can mean for this transition?

- What is the role of the ITS World Congress 2021 in this?

Hamburg wants to bring about the mobility transition. What do you think that Smart Velomobility can mean for this transition?

- Is there enough attention for cycling in Hamburg's (or general) ITS strategy in your opinion?

What do you think about the balance between different modes of transport?

- In terms of funding etc.

What do you think about the balance between different interests?

- Of the average Hamburg citizen and (international) commercial parties?
- Between users of different modes of transport, especially cyclists and pedestrians?

How are the interests of citizens considered?

- Has there been citizen participation?

Closing

So, if I understood you correctly: [summarizing the main points of the interviewee].

Is there anything you would to add to the interview?

STOP RECORDING

I have now stopped the recording. Please let me know if you have any questions or concerns. In the coming months I will work out the results of the interviews. Would you like to receive a copy of the final thesis?

Thank you very much again for participating in this research.

Summary in German

Smart Velomobility in der ITS Strategie der Stadt Hamburg

Die Stadt Hamburg will durch intelligente Maßnahmen im Bereich Verkehr die städtische Lebensqualität und das ökonomische Wachstum verstärken. Um die Stadt intelligenter zu machen, wurde die Intelligent Transport Systems (ITS) Strategie entwickelt (Hansestadt Hamburg, 2021b). 2016 hat der Senat der Stadt Hamburg die ITS Strategie beschlossen und zum Oktober 2021 wird der internationale ITS Kongress organisiert. Die Bemühungen der Stadt Hamburg waren bereits erfolgreich. Laut Bitkom gilt Hamburg deutschlandweit als besonders smarte Stadt. Sowohl in der allgemeinen Smart City Rangliste als auch im Bereich Mobilität, hat die Stadt 2020 die höchste Punktzahl aller deutschen Großstädte erreicht (Bitkom, 2021).

Mobilitätswende

Die Hansestadt Hamburg will auch die Mobilitätswende vorantreiben. Im Koalitionsvertrag 2020-2025 wurde festgelegt, dass der ÖPNV Anteil im Rahmen des Hamburg-Takts von 22 Prozent im Jahr 2017 auf 30 Prozent im Jahr 2030 steigen soll. Der Radverkehrsanteil soll bis 2030 auf mindestens 25 Prozent steigen (Hansestadt Hamburg, 2020).

Smart Velomobility

ITS Maßnahmen im Bereich Radverkehr werden auch als Smart Velomobility bezeichnet (Behrendt, 2016, 2019, 2020). Durch Smart Velomobility kann der städtische Radverkehr sicherer, schneller und komfortabler werden (Behrendt, 2016, 2019, 2020; Interreg North Sea Region, n.d.; Nikolaeva et al., 2019). Jedoch hat Behrendt (2019) in ihrer Untersuchung herausgefunden, dass das Fahrrad im Smart City Diskurs nur einen geringen Stellenwert hat. In meiner Masterarbeit wurde durch Dokumentenanalyse und Interviews mit verschiedenen ExpertInnen untersucht inwiefern Smart Velomobillity Maßnahmen in Hamburgs ITS- und Radverkehrsstrategie berücksichtigt werden und welchen Beitrag sie zur Mobilitätswende leisten können.

Fazit und Ausblick

In Hamburg gibt es einige Smart Velomobility Projekte. Einige fokussieren sich vollständig auf den Radverkehr, wie das PrioBike-HH Projekt. Ziel ist ein schneller und sicherer Radverkehr durch lichtsignalgesicherte Kreuzungen. Außerdem gibt es Projekte, bei denen der Radverkehr nur als einer der Verkehrsmittel berücksichtigt wird. Ein Beispiel dafür ist das GeoNetBake Projekt, womit Verkehrsteilnehmer in Echtzeit über Baustellen informiert werden. Ansonsten gibt es ITS Lösungen wie der HEAT Shuttle, wovon auch RadfahrerInnen profitieren können. Der HEAT Shuttle kann vor allem in den Randgebieten der Stadt eine schlechtwettertaugliche Alternative zum Fahrrad bieten.

Der Vorteil von Smart Velomobility ist, dass mit Hilfe von gezielter Datennutzung besser auf die Bedürfnisse der RadfahrerInnen eingegangen werden kann. Die befragten Experten haben die Aussage des Interreg Projektes Bicycle und ITS (BITS) bestätigt, dass mit den Daten Lösungen entwickelt werden die das Radfahren sicherer, schneller und komfortabler machen können (Interreg North Sea Region, n.d.). Ein weiterer Vorteil ist, dass durch die Digitalisierung Hauptunfallschwerpunkte schneller entschärft werden können als über konventionelle infrastrukturelle Maßnahmen. In Hamburg werden beispielsweise alle städtische LKWs mit Abbiegeassistenten ausgerüstet.

Smart Velomobility bietet jedoch keine Universallösung. In Hamburg wurde von befragten Experten betont, dass infrastrukturelle Maßnahmen mindestens so wichtig oder sogar wichtiger sind als Smart Velomobility, um den Radverkehr sicherer und damit attraktiver zu machen. Es müssen Maßnahmen eingesetzt werden, die für die jeweilige Stadt geeignet sind. Das Fahrradfahren ist in Hamburg im Vergleich zu Fahrradstädten in den Niederlanden und Dänemark deutlich gefährlicher

(Pucher & Buehler, 2008). Hamburg und andere Städte mit einer ausbaufähigen Fahradinfrastruktur, sollten sich daher vor allem auf Projekte fokussieren, die die Sicherheit verbessern. Projekte, die auf die Geschwindigkeit und den Komfort ausgerichtet sind, können zwar auch die Attraktivität des Fahrradfahrens verbessern, stehen jedoch an zweiter und dritter Stelle. Auch sollen die Interessen der verschiedenen Zielgruppen (bspw. alt, jung, digital native, digitaler Einwanderer, reich oder arm) stets berücksichtigt werden.