# EUROPEAN MOBILITY VENTURE

Munich | Copenhagen | Oslo | Amsterdam 2021 Report





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### **EXECUTIVE SUMMARY**

The report encompasses different innovations for various mobility-related fields which provide possible solutions to problems that not only challenge Munich but many other cities around the world. Important to note is that the success of every mobility project is not only based on strong innovation spirit but also on effective cooperation of all stakeholders, often with the involvement of citizens. The student teams critically analyzed all projects and created a concentrate of knowledge worth sharing - so that the City of Munich can truly benefit from this report's findings.

Amsterdam adapts a cycling-friendly infrastructure, innovative traffic management, and street experiments that significantly contributes to a modal shift away from the car towards more cycling. With a large number of implemented cycling solutions and their high-quality, Copenhagen is ranked as the world's most bicycle friendly city. Oslo has the highest adoption rate of electric vehicles (EVs) in the world, which helps decarbonize the transport sector, but at the same time strives to shift the modal split from private vehicles towards alternative modes like public transport, cycling and walking.

The three cities analyzed are successfully achieving sustainable mobility goals and serve as an example in this field. Oslo and Amsterdam take the lead in transition to electric vehicles: while Oslo has the highest share of EVs in the world, Amsterdam boasts the highest charging station density. However, high private car use rate unites all cities which, in its turn, contributes to high congestions on the roads similar to Munich.

All cities take measures to increase the attractiveness of alternative transportation modes, like active mobility and public transport: Copenhagen and Amsterdam are best-positioned in terms of active mobility, leaving Oslo and Munich behind. When considering fatal crashes involving active modes, all three cities demonstrate high road safety. Therefore, Munich can learn from best practices applied in these cities and add to its already existing measures.

In case of public transport, Amsterdam lags behind other cities, despite lower fares, while Copenhagen is in the lead with public transit affordability, annual trips per capita, and station density in the service area (Wuppertal Institute 2018). In city centers of Munich and Oslo public transportation becomes predominant, while bike use stays seasonal for both cities.

All cities presented in this report are responding in a timely manner to the challenges of high population growth, traffic congestion and CO2 emission by introducing efficient measures for reaching their sustainable urban mobility goals.

### INTRODUCTION

Today, more than half of the world's population lives in cities and is responsible for three-quarters of global CO2 emissions. In cities, 40% of CO2 emissions and 70% of other pollutants are caused by traffic. With increasing traffic volume, cities not only contribute significantly to climate change, but also face several challenges, such as high levels of congestion, air and environmental pollution, noise, as well as traffic accidents - all of which negatively affect the quality of life of residents (Coalition for Urban Transitions 2019). Mobility, and urban mobility in particular, therefore plays a fundamental role in addressing climate change. The mobility of the future must be completely transformed: it must be more sustainable and oriented toward people's needs. The Covid-19 pandemic further demonstrated that cities need to become more resilient to crises, not only pandemics but also impending climate crises. Many cities have taken up this challenge and are re-imagining urban mobility, wanting to make it more environmentally friendly and socially inclusive.

Around the world, best practices can be identified that are worth analyzing. As part of the newly founded Munich Cluster for the Future of Mobility in Metropolitan Regions (MCube), the research project euMOVE (European Mobility Venture) examines urban mobility solutions and innovations in European cities and their applicability to the City of Munich. Based on an analysis of mobility pioneers in Europe, the cities Amsterdam, Copenhagen and Oslo were selected.

Twelve students of the Technical University Munich, belonging to the Department of Civil, Geo & Environmental Engineering, the Munich Center for Technology in Society, the Department of Mechanical Engineering, the Department of Electrical and Computer Engineering, the TUM School of Governance, the Munich School of Engineering, and the TUM School of Management participated in this year's euMOVE project and wrote the following report.



### METHODOLOGY

This research project has been conducted by a total of twelve students who were divided into three groups of four, worked with one supervisor from the involved university chairs and focused on one city – Amsterdam, Copenhagen or Oslo – and analyzed mobility projects and innovation there. The cities were visited in the period of June to July 2021 for about two weeks in which

- (1) interviews with local transport authorities and politicians, mobility companies, start-ups and initiatives as well as citizens,
- (2) (participant) observation of public/individual modes of transport and traffic systems as well as mobility seminars and workshops, and
- (3) document analysis of policies, newspaper and company articles

were conducted to gather data about different mobility projects. The Covid-19 pandemic did not extensively restrict the researchers to conduct remote research – while abiding and respecting the safety regulations in place, field observation and in-person interviews were still possible. However, a number of interviews was also conducted via phone or online on the platforms Zoom or Skype. In order to be able to compare the researched mobility projects, the different innovations are thematically assigned to one of the following five clusters:

#### 1. Public Mobility & Software Solutions

Realization of digital mobility services like Mobility as a Service, Mobility on Demand, simulations of traffic flows, crowd management

#### 2. Vehicle Technologies & Energy

Innovative charging infrastructure solutions, electrification of all types of ground-based vehicles and the delivery traffic, autonomous shuttles, and automated last-mile services

#### **3. Active Mobility**

Experiments and innovative solutions in pedestrian and bicycle traffic

#### 4. Urban Planning

Ideas for optimal (re)design of public space with focus on active modes of mobility, public transport, and the reduction of cars

#### 5. Co-Creation

Innovative approaches to solve mobility challenges with the involvement of society

Furthermore, in order to assess the concrete effects on urban mobility in a comparative way, every project presented is evaluated in terms of its contribution to the improvement of the **quality of air**, **space** and **time** - based on the strategy of MCube (2021). **Air** reflects traffic-related environmental pollution and, consequently, stands especially for local air pollution by nitrogen dioxide (NO2) or particulate matter (PM) as well as for local noise pollution. Additionally, the reduction of CO2 emissions is of high importance and thus global climate protection. **Space** concerns the impact of mobility innovation on public urban space which is becoming increasingly scarce in many cities. In this respect, it is important to create new shared public spaces that are accessible to the entire population and ideally prioritized in favor of active modes of mobility as well as public transport. The goal behind this is to increase the quality and duration of stay in the neighborhood. Further important issues of quality of space include traffic safety and social security. **Time** refers to the efficiency of the transport system and accessibility, i.e., the possibility of reaching all everyday destinations comfortably and in a short period of time. This can be realized by e. g. the reduction of trip lengths for selected trip purposes ("15 minutes city"), smart control of traffic flows, as well as intelligently connected and multimodal mobility solutions.

The impact on each of the three aspects is evaluated qualitatively for every single analyzed mobility project. In order to highlight the cities' individual approaches to similar mobility challenges and to give further interesting insights, the report includes a cross-city analysis with Munich in which a comparison by clusters and similar measures is conducted.



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### GLOSSARY

#### BEV: Battery electric vehicle

BEVs are powered exclusively by one or more electric motors and have a large battery, allowing ranges of at least 100 kilometers.

**BESS**: Battery Energy Storage System

A BESS is a large-scale energy storage system that can store energy from solar panels or the electric grid. It can be used for certain energy services, e.g., peak shaving.

B-HPC: Battery-Buffered High Power Charger

A B-HPC is a high power charging technology with integrated battery buffer, enabling the use of renewable energies for charging and preventing peak loads on the energy grid by high power charging.

DSO: Distribution System Operator

DSO is responsible for operating and maintaining the electricity distribution grid.

ICE: Internal Combustion Engine

**OCPP**: Open Charge Point Protocol

OCPP is an open communication standard and regulates the communication between a charging station and a backend system.

**OEM**: Original equipment manufacturer

OEM provides the components in another company's product, working closely with the seller of the finished product.

#### **Peak Shaving**

Peak shaving refers to the smoothing of load peaks in electricity consumption. These peaks are not only relevant for grid stability, but also for power purchase costs.

PHEV: Plug-in Hybrid Vehicles

PHEVs both have a combustion engine and electric motor and a relatively large battery which can be charged externally and allows for locally emission-free electric driving.

#### PV panel: Photovoltaic (solar) panel

PV panel is an assembly of photo-voltaic cells that serve for generating electrical power from solar radiation.

#### **Smart Charging**

Technology that implies control of the charging session of an EV by means of changing its charging speed, taking into account various data (e.g. local renewable generation, next planned departure, current and desired state of charge of an EV, etc.) and forecasting the future demand.

6 - Glossary

SOC: State of Charge

Level of charge of an electric battery

V2G: Vehicle to Grid

V2G is a technology that allows energy from electric vehicle batteries to be returned to the electrical power grid. Bi-directional charging stations are required to realize V2G.



### MUNICH, GERMANY

Munich is the capital of the state of Bavaria in south-eastern Germany, well known for hosting the world's largest Volksfest: the Oktoberfest. The city is the third largest in Germany by population and has the strongest economy compared to other major German cities (München 2021a), with the entire Munich metropolitan area being one of the richest areas in Europe.

This economic wealth and growth have over many decades lead to a city with different modes of mobility being important to the daily life of its citizens, while at the same time providing for challenges to be faced in the future. With one of Germany's big car companies - BMW headquartered in Munich, and AUDI headquartered not far from Munich in the City of Ingolstadt, the car plays a major role in the area. This can be seen in many aspects. Many people work in the automotive industry, a lot of spending is done for research on automobile technologies and the car is still the dominant form of transportation for many of Munich's citizens.

Besides the focus on cars, Munich has a well-established public transport network, and the importance of cycling has risen significantly in the last two decades. Both the road network as well as the public transport network are reaching their limits, presenting a challenge to the city for their future mobility strategy. The City of Munich identified additional challenges with a rise in population, environmental and health protection, and the importance of digitalization in the mobility sector (München 2021b).

This chapter will present a deeper overview of urban mobility in Munich, laying the foundation for the analysis of the cities of Amsterdam, Copenhagen and Oslo.



All entries refer to the year 2020 unless stated otherwise



### 84K

**GDP PER CAPITA** (2019 USD)

### 44.9%

### SHARE RENEWABLES ELECTRICITY MIX **GERMANY**

### 44

### DAYS WITH LOW TRAFFIC

RANK 50 / 73

RANK 15 / 20

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### **LOCATION ANALYSIS**

Munich is not only the Bavarian capital, but also known as the leading eco-nomic center of Germany. Besides, the Munich metropolitan region is the metropolitan area with the lowest unemployment rate in Cermany (IKM, 2021).

#### Economy

- GDP: €116.65B (2018)
- GDP per employed person: €103,355(2018)
- Unemployment rate: 4.5% (2020)

In the nationwide comparison, Munich has the highest GDP per employed person and the lowest unemployment rate. It averaged 4.5% in 2020 as a result of the Covid-19 pandemic, following an all-time low of 3.3% in 2019 (Landeshaupstadt München 2021c).

With six DAX-listed companies, Munich is home to the largest number of DAX-listed companies in Germany (Landeshauptstadt München 2020). Munich connects a range of mobility stakeholders, from large corporations, mobility start-ups, mobility hubs and ecosystems, to NGOs or mobility stakeholders in the City of Munich or university and research institutions.

#### **Political System**

Since 2020, Munich has a government coalition consisting of the Greens, SPD, Rosa Liste and Volt (Effern 2020).

#### **Education & Research**

Munich is home to three large public universities: Ludwig Maximilian University of Munich, Technical University of Munich, and Munich University of Applied Sciences, the first two of which have been recognized as universities of excellence.

In addition, there are further smaller, private and public universities and academies. Furthermore, a number of renowned research institutes are located in Munich, including Fraunhofer-Gesellschaft, Max Planck Society for the Advancement of Science e.V., and Helmholtz Center - the German Research Center for Health (Landeshauptstadt Environmental München 2019b).



### **RENTAL PRICES MAP**



Figure 1.3: Rental prices in Munich by district in 2019

### LAND USE MAP



Figure 1.4: Land use in Munich in 2021

LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN



Figure 1.2: Munich universities logos



Rental prices in Munich by district in 2019

#### Rental price per square m

15.70€ - 16.70€
16.70€ - 17.70€
17.70€ - 18.70€
18.70€ - 19.60€
19.60€ - 20.60€
20.60€ - 21.60€
21.60€ - 22.60€

- 7 Sendling-Westpa 8 Schwanthalerhöh
- 9 Neuhausen-

- 4 Berg am Laim 5 Trudering-Ri
- 16 Ramersdorf-Perl
- 17 Obergiesing-Fasang
- 18 Unterglesing-Harlaching 19 Thalkirchen Obersendling

- 4 Feldmoching-Hasenberg

Land use types in Munich 2021

Land use types Munich



## **URBAN MOBILITY ANALYSIS**

Munich was Germany's most congested city in 2020 (Hauser 2021). However, the city has ambitious goals to reduce traffic and make alternative modes of transport more attractive.

The citizens of Munich rated walking and public transport as the best mobility options in 2018, followed by cycling in second place and cars only taking the last place (Follmer & Belz 2018). Despite this rating Munich can be described as a car-centric city, with a third of all daily journeys undertaken by car. While this number is decreasing relative to other modes of mobility, with especially cycling and public transport taking an increasingly larger share over the last two decades, the absolute number of journeys is increasing across all modes of mobility. Yet the city is working on several initiatives with the goal of creating new mobility ideas for the City of the future (München, 2021d). The major parts of Munich's mobility strategy include plans like investments in new public transport projects, improving the cycling infrastructure, improving commuting into the city, a car-free oldtown or the promotion of innovative mobility solutions.

With 394,000 people commuting into the city and 186,00 commuting out of the city on a daily basis, Munich's connection to its surrounding area as well as other major German cities plays an ever-important role in Munich's approach to urban mobility (Pendleratlas 2021).

#### Public Transport

Together with the walkability of the city, the citizens of Munich rated public transport as the best form of mobility in 2017 (Follmer & Belz 2018). Munich offers diverse options for public transport throughout the city, including 8 S-Bahn lines on 434 km of track, 8 U-Bahn (metro) lines on 95 km of track, 13 tram lines on 82 km of track and 511km of city busses (MVV München 2021a). This offering is extended by regional trains and busses connecting the surrounding area to the City of Munich. In the year 2018 722,3 million passengers traveled 7,324 million kilometers using the public transport network of Munich (Follmer & Belz 2018). Both the extensive network and the number of travelers ranks Munich among the best public transport networks in Europe. Unique to Munich, along the so-called "Stammstrecke", the main S-Bahn track runs through the city from west to east with all eight lines on the same tracks. This leads to very short waiting times for the next train of only a few minutes to cross the city with all major connections to metro or bus running in other directions being accessible at stations on the "Stammstrecke". A major development in recent years was the change in pricing by redefining pricing zones in Munich, the entire



Figure 1.6: Modal Split in 2017



Figure 1.7: Bicycle Network Perception map of Munich. Red lines indicate stressful cycling, green indicate comfortable cycling.

city being declared as one zone of similar pricing and six additionally zones in rings around the city leading to the surrounding cities as well as the airport.

#### **Bicycles**

The importance of cycling has risen with respect to the mobility mix of Munich over the last two decades (Follmer & Belz 2018). Over 80% of all households in Munich have at least one functional bicycle, amounting to over one million bikes in Munich. In 2017 there were 25.000 electric bikes present in Munich, with an evergrowing number of electric bikes being sold. Bike lanes and bike paths are mostly found on major streets throughout the city, as well as alongside streets and through parks leading into the city center. Yet there are still many parts of the city with few or no bike paths at all, leading to cyclists having to share the streets with cars. This leads to a rather negative perception of the bike network in the city center. Following a citizen initiative, the City of Munich is currently trying to combat this, by creating a new circle bike lane around the oldtown of the city (München 2021e).

#### Walking

With 24% of all journeys done by foot, the importance of walking is a not to be underestimated in Munich (Follmer & Belz, 2018). About half of all citizens in Munich complete at least one of their daily journeys entirely by foot. This number is significantly higher in the more densely populated city center compared to the outer suburbs. Walkability is rated above average in almost the entire city center, yet

Figure 1.5: Modal Split in 2008

there are also highly walkable areas in the surrounding city districts of Munich. This can mostly be attributed to the historical development of the city with several centers and the city's strategy of developing centers into inner city hubs in the future.

#### Private Cars

Comparing Munich's modal split over the last two decades it could be concluded that the private car has lost importance compared to public transport or cycling, yet due to the overall increase in traffic the number and length of journeys undertaken by cars has been increasing over the years (Follmer & Belz 2018). While only a third of all journeys in 2017 are done by car, the length of these journeys has increased. The role of the car is of different importance within the suburbs of Munich, having way more car owners and users than the inner city. The number of cars registered in Munich in 2019 amounted to 729,845 with combustion engine cars making up about 95% of all cars (Statistisches Amt 2021). One of Germany's big car manufacturers - BMW - is headquartered in Munich, leading to a certain car culture present in the city. A rising trend over recent years is carsharing with 21% of all citizens in Munich having one or more car sharing accounts (Follmer & Belz 2018). Yet the number of people using carsharing for their daily commute is still very low.



Figure 1.8: Walkability map



Figure 1.9: Noise Map Munich: Blue: >75 dB, dark red: 70-75 dB, red: <70 dB, green: noise reduction measures



Figure 1.10: Public Transport Map of Munich



## PROJECTS

Public Mobility & Software Solutions
MVG Swipe+Ride
MVGO
Vehicle Technologies & Energy
Easyride
TEMPUS
Active Mobility
Radentscheid & Altstadtradlring
Pop-up Bicycle Lanes
Urban Planning
Umparken Schwabing
Autofreie Altstadt
Co-Creation
Inzell Initiative
City2Share

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### **MVG SWIPE+RIDE**

*MVG Swipe+Ride is a pilot project that aims to explore dynamic and distance* driven price models rather than fixed rates. The project is part of the eTarif which is a smartphone-based check-in and check-out system for public transport (MVV München 2021b).

#### Motivation

The advantage of the model is that only the actual trip distance has to be paid for. Especially for people that are currently only doing little to no trips by public transport this is quite handy as they do not have to buy a weekly/ monthly subscription (MVV München 2021c).

#### Implementation

The costs of the trips are split in a reduced and a regular fare. The reduced fare is applied for stations with few departures, while the regular fare comes into effect for busy stations (e.g. central station). The total costs consist of a base fare that is always applied and a price per km driven as shown in the table. Though the distance is not calculated based on the railways track length but on the beeline distance between the start and end station of the trip. By making more trips per month the customer gets a price reduction on the monthly invoice. Four rides per month reduce the costs by 10%, while six trips bring in 20% and eight trips 30% (MVV München 2021d).

The process of booking or buying a ride is fairly simple. Once a customer has registered on the website of Swipe+Ride and downloaded the app, he or she just has to swipe right on the app before getting on the ride. To end the ride at the destination a simple swipe to the left is enough. The customer can see the ride price afterwards and the invoice is done automatically. The pilot project started at the end of October 2020 and goes on for two years. The market research that runs in parallel to it goes on for another six months.

The software and the smartphone app of the eTarif is provided by the Swiss company FAIRTIO. They specialized on the distancetravelled price model.



**STAKEHOLDERS** MVV, Munich, Bayr. Regiobahn, S-Bahn München, Verbund Landkreise im MVV, FAIRTIQ

#### **AFFECTED TRANSPORT** Public Transport



#### Outcomes

After half a year of testing, the first feedback loop was done. Main results were that most of the customers (75%) are working from home at least most of the time and are therefore ideal for the project concept. More than half of the users are between 30 and 49 years old and only one quarter of all of them lives outside of the city. Their biggest demand was an automatic check-out function which has been implemented by FAIRTIO (MVV München 2021b, 2021c).

#### Discussion

While the concept and their product are already usable throughout Switzerland and Lichtenstein, only 11 transport associations in Germany use it (FAIRTIQ 2021). Though cities like Bremen, Flensburg and Magdeburg have already successfully implemented the concept - some of them already in 2020 (AktivBUS Flensburg 2020). Currently the eTarif is only accessible to a limited number of 5.300 test customers that are obliged to regularly share feedback on their user experience.

#### Outlook

The concept of a distance-based price model has been proven successful as Flensburg, Bremen and Switzerland have shown. Additionally, the comments of the first feedback loop support the MVV and their pilot project and promise good chances for it to be implemented for daily operation after the test phase.

	Base price	Price per km
Reduced fare	€1.00	€0.20
Regular fare	€1.10	€0.30

Table 1.1: Cost overview MVG Swipe+Ride



S 🕕 805 Tram R

### MVGO

MVGO is an app of the MVG that provides a platform for multimodal mobility. It is free to use and allows the user to get information on modes as well as to buy tickets (Trafi 2021).

#### **Motivation**

Throughout the time more and more solutions and offers appeared in Munich. To bundle public transport and sharing providers the MVG developed an app called MVGO.

The main idea behind it is to encourage people to leave behind their private car and shift to shared mobility (Benthien 2021).

#### Implementation

Currently there are five different sharing options that can be booked in addition to public transport tickets:

- MVG Bike
- Emmy Electric-Scooter
- Tier Electric-Scooter
- Voi City-Scooter
- Tier City-Scooter

After downloading the app MVGO one has to create an account at M-Login which is the centralized service portal of the Stadtwerke München.

The all-in-one solution allows an easy transaction and a built-in drivers license verification tool. The trip planning tool adjusts to real time traffic situations and shows the location of the vehicle in real time (Trafi 2021).

The platform for MVGO is provided by Trafi which is the world's leading mobility-as-aservice technology company. They do not only provide platforms for cities but also for companies and their internal mobility program. Trafi is used in the same way by the cities of



Berlin and Vilnius where the company is from. In Switzerland things were taken a step further where the Swiss Federal Railways SBB and the public transport operators of Zurich, Basel and Bern founded a cooperation for a cross-city Maas platform called "yumuv". With a single registration user can access mobility solutions in each of the cities (Trafi 2020).

#### Discussion

Developing an app that contains different modes of transport improves the user experience drastically. Unfortunately though, not all modes or providers can be booked through the app which leaves the user behind with different apps and accounts once again. Nevertheless, the app allows constant updates and new mobility solutions to be added. With that potential, MVGO can develop into a holistic mobility platform and combine the various mobility offers that can be found in Munich already.

#### Outlook

On a longer term MVG will probably follow the transport operator in Berlin BVG by adding more mobility solutions (Reichel 2021). When the app launched in Berlin in 2019 people were already able to book rental bicycles of Deezer, city scooters of Tier electric scooter of Emmy, shuttle-services of Berlkönig as well as rent cars from sharing stations of Miles, DB Flinkster, Mobileeee and Oply (Weiß 2019)..

The project has the ability to make people switch their private polluting cars for public transport

AIR

#### SPACE

Easy and holistic PT planning can make people get rid of their parking spot



Figure 1.13: MVGO App



### EASYRIDE

The project Easyride examines what effects automated driving can have on mobility and traffic and what the public sector should do to control and use this innovation for the benefit of the citizens.

#### **Motivation**

The overall aim of Easyride is to develop a tool kit that cities can implement to use the new technology for the benefit of their citizens. The results will then flow into the new mobility plan of the City of Munich and be made available to other municipalities in the form of a guide. The project was initiated in Munich in October 2018 and is backed by the Federal Ministry of Transport and Digital Infrastructure (BMVI 2021).

#### Implementation

During the project phase different types of vehicles such as cars, bus shuttles and city buses were examined using various simulations and scenarios. The four scenarios are clustered in a matrix that is defined by two axes. The type of mobility – individual or shared – marks the first axis and the level of regulation – little or strong – marks the second axis (Easyride 2019).

#### Outcomes

To this end, new pooling and sharing services are being developed and modeled using various scenarios, and their effects are assessed. Empty trips are to be minimized and the occupancy rate increased in order to reduce motorized individual traffic (MIT) on the road. The legal framework for automated and networked driving is to be further developed for future providers, but also for municipalities that have to fulfill their control function. New technologies are being tested, such as the control and networking of automated vehicle fleets. These are being further developed by the mobility providers involved in the project, such as BMW and the Munich municipal utilities (Mobilitätsreferat, n.d.).





#### AFFECTED TRANSPORT

#### Private cars

#### DURATION

10/2018 - 06/2021

As part of the EASYRIDE research project, BMW is looking into the potential of autonomous driving in the context of on-demand mobility concepts. The focus is on the effective use of driverless vehicles to solve the current traffic problems in large cities. For this purpose, BMW is developing, among other things, a ride pooling process for efficient travel brokerage.

With the help of this ride-pooling algorithm, carpools can be formed automatically for people with a similar starting point and destination. This ride pooling process is checked for its technical maturity on the basis of several internal and external field tests.

In addition to the technology testing, the service design and the app are also evaluated through customer feedback. In this way, the ride pooling process can be optimized iteratively (Easyride 2019).

#### Outlook

In the future regulations and laws have to be adapted even further, to bring more pilot field test to the streets of Munich. A successful carpooling concept could ease the traffic situation of Munich and further, make the ownership of private cars redundant. The successful project outcomes and findings prove the concept of autonomous driving to be helpful in the long term mission of solving urban traffic issues.





Figure 1.14: Part of the Easyride research project: an autonomous shuttle bus

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### TEMPUS

At the beginning of this year, the go-ahead was given for the pilot project TEMPUS, a test field for automated and connected driving in the north of Munich, which is intended to improve traffic safety and traffic flow. The project period is 30 months and starts in 2021.

#### **Motivation**

Starting this year, automated and connected driving is being tested in a real environment in the north of Munich. The pilot project is called TEMPUS (short for "Test Field Munich - Pilot Test Urban Automated Road Traffic"). To this end, the traffic infrastructure is being equipped with intelligent technology that will make it possible to test self-driving cars. Testing in this real environment is intended to find out what framework conditions automated driving requires and how road users react to it (Landeshauptstadt München 2021i).

#### Implementation

The project receives funding of around 11 million euros from the Federal Ministry of Transport and Digital Infrastructure and will run for 30 months. In a collaboration between the City of Munich and twelve other project partners, including the Technical University of Munich, BMW, Siemens, UPS, the Stadtwerke München (SWM) and the Free State of Bavaria, the project will be operated. It will test, for example, a virtual turning assistant, the efficient use of real-time traffic information or a traffic light prediction function. In addition, possible applications of automated and connected driving in public transport will be investigated (Reichel 2020; Landeshauptstadt München 2021i). In order to make the test environment as real as possible, public transport and delivery transport are to be included in the test field. For this reason, the company UPS is also on board.

The bundled expertise is intended to create the technical prerequisites to enable automated and networked traffic. The real-world environment will enable an assessment of the necessary framework conditions and the potential challenges, including how citizens



**STAKEHOLDERS** Munich Mobility Department and project partners from research and industry

#### AFFECTED TRANSPORT

automated and connected mobility

#### **DURATION** 2021-2023

react to the technology and the environment. The test site will be supplemented by citizen surveys to obtain and, at best, incorporate their perspectives (Schubert 2020; Landeshauptstadt München 2021i).

#### **Outcomes & Discussion**

One of the technologies to be tested is platooning, an automatic-electric bus system. A prototype is currently being built under the leadership of the Karlsruhe Institute of Technology (KIT), Stadtwerke München (SWM), and the Dutch vehicle manufacturer Ebusco. This prototype is to be tested next year at the Munich test site. In addition, numerous other solutions are being tested. Since the project is still quite young, the outcomes will have to be awaited (Karlsruher Institut für Technologie 2021).



Figure 1.15: Platooning





### **RADENTSCHEID & ALTSTADTRADLRING**

Both the Radentscheid and the Altstadtradlring are two bicycle referendums started in 2019 aiming to improve cyclability in Munich by 2025 (Bündnis Radentscheid München, n.d.).

#### **Motivation**

With cycling becoming more and more popular in Munich and cars still being favoured by the city's shape and design, things have to change (infas 2019). And exactly that is what the two referendums were trying to achieve.

#### Implementation

The initiators behind the referendum were motivated citizens, as well as the ADFC (General German Bicycle Club) München, the green and the left party, and many other governmental and non-governmental organizations and institutions (Bündnis Radentscheid München n.d.).

The Radentscheid - the more extensive referendum - contains 5 major fields of action.

Safe and convenient cycling facilities, a citywide and continuous cycling network, safe and stress-free intersections, well-distributed bicycle parking as well as an area-efficient and socially equitable distribution of public space (Bündnis Radentscheid München 2020).

The Altstadtradlring aims to develop and implement a continuous bicycle route around the old town of Munich. With frequently used and highly stressful streets for cyclists, the old town ring should be used to improve the situation for cyclists. Therefore, the pedestrian zone in the centre has more space for pedestrians as cyclists will more likely switch to the faster and more convenient bicycle ring. At the same time, it should function as a turntable for future star-shaped bicycle highways that go to Munich from other outer cities (Bündnis Radentscheid München 2020).





**STAKEHOLDERS** City of Munich, Bündnis Radentscheid, Citizens, many other organizations AFFECTED TRANSPORT

#### Before the Radentscheid and the Altstadtring became a successful referendum, they had to surpass 33.000 signatures in the first step and 100.000 signatures in the second step.

Already after three months, the first phase was stopped as both referendums achieved twice the needed signatures. In the second step almost 160.000 votes were registered (Bündnis Radentscheid München 2019). The number of votes once again showed to the initiators and officials how important the topic was.

#### Outcomes

Despite these measures, not much has happened yet. Bicycle paths have been built but not as a seperat lane but mostly as coloured lanes on existing roads in between cars and trucks. When those want to switch on to a turning lane, they have to cross the bicycle lane and produce - if they want or not - a dangerous situation. One of the main roads in Munich, the Ludwigstraße, is supposed to be reconstructed and plans were published in April 2021. In those plans, bicycle paths have a width of 2,00m in one direction even though the referendum prescribes at least 3,00m. Cars on the other hand are being prioritized again and get a 9,00m width in one direction (Bayerischer Rundfunk, 2021). According to the Radentscheid, a feasibility study found out that in the future 20.000-25.000 cyclists are expected on this road on a daily basis (Bündnis Radentscheid München 2021a).





Figure 1.16: Frauenstraße as designed in Altstadradlring concept

#### **Discussion & Outlook**

It seems that the implementation of the two referendums will end like the bicycle highway that was supposed to connect the centre and the City of Garching in the north of Munich. While the planning process started in 2016 not a single meter has been built until today (Kronewiter & Mühlfenzl, 2021). With more and more people getting on a bicycle for their daily trips one can and has to expect more things to change in the near future.



Munich - Active Mobility - 29

### **POP-UP BICYCLE LANES**

Pop-up bicycle lanes were temporary measures to improve cyclability in Munich in 2020. During the Covid-19 pandemic, the number of cyclists increased as people switched public transport to bicycle.

#### Motivation

The Covid-19 pandemic led to an increase in cyclists of 20% in April 2020 in comparison to the previous year. Unfortunately, though, the number of accidents increased by 16% in the first four months of the same year. So the City of Munich, as well as other cities around the world, decided to improve the situation for cyclists.

#### Implementation

That's why in May 2020 the City of Munich decided to build non-temporary bicycle lanes on five roads across the city in June 2020. The yellow marked bicycle lanes were easy to construct and provided cyclists with additional comfort, travel speed and safety. Throughout the summer the temporary lanes were very popular and highly appreciated by Munich's cyclists (Peter, 2020).

It was very surprising for all of them as the City of Munich decided to end this temporary field test and deconstruct the lanes at the beginning of November 2020. The reason behind it was that they were just a temporary measure, more serious and longer solutions are required and that the field test has to be evaluated now (Schubert, 2020). According to a local SPDpolitician the yellow road markings of the popup lanes would not be visible enough throughout the winter season. Better no bicycle lane than a poorly visible one (Steinbacher, 2020).



City of Munich, Bündnis Radentscheid, Citizens

#### Outcomes

After the evaluation process the City of Munich decided in March 2021 that the temporary measures of the previous year are being turned into real bicycle lanes. The yellow paint is replaced by regular white road markings. The costs were estimated to account to 600,000 Euro (Schubert, 2020). The conservative party of Munich expressed their concerns as parking spots have to be taken away from car users (Schubert, 2020). Until May 2021 four of the five former pop-up bicycle lanes were rebuilt as regular bicycle lanes. The mayor of Munich, Dieter Reiter, stated that these new lanes are also just temporary measures until the city planners found serious constructive solutions for cyclists on these roads (muenchen.de, 2021).

In June 2021 the automotive club "Mobil in Deutschland" brought an action against the new bicycle lanes as they would take away space of the - as they imply - "main mode of transport in Munich" (SAT1 Bayern, 2021).

#### Discussion

Pop-up bicycles lanes were a popular measure to improve cyclability in cities. In London, things were taken to another level as more than 100km of new bicycle lanes were taken into action (Einzel 2021). While London rightfully took the lead of pandemic-related mobility adaptation, Munich still implemented bicycles lanes the have proven to be needed and wanted but also to be highly appreciated and extensively used. Further, the City of Munich





Figure 1.17: Pop-up bicycles lane in the Rosenheimer Straße

decided to transform the temporary lanes into permanent bicycle lanes and thereby show their will to improve the situation for cyclists.

Munich - Active Mobility - 31

### **UMPARKEN SCHWABING**

UMPARKEN Schwabing-West was a research project in which households swapped their private car for a mobility budget. The free parking space has then been used for different purposes.

#### **Motivation**

The car dominated scenery in Munich, especially the amount of public space private cars use for parking was the main intention behind the research project 2020. The project was initiated by the Digital Mobility Hub UnternehmerTUM. The main idea is to develop new mobility solutions based on the findings of the experiment (Digital Hub Mobility 2021).

#### Implementation

The project was implemented in five steps. First of all, the project team had to conduct research regarding urban space and mobility and identify potential study locations. Schwabing-West has been picked due to the already existing mobility infrastructure and the necessity for fewer parking cars. By distributing flyers, conducting interviews and holding information events, 8 households were selected to take part in the 4 weeklong research project. In the third step, the private cars of the participants were moved outside the city to create free space in the neighbourhood. By parking them at park & ride facilities, easy and free access to their cars was guaranteed. To support the participants with their new way of moving around the city, they received a mobility package with information about urban mobility in Munich. The package was extended through the cooperation with the start-ups Veomo, envcle and Moovster that provide additional mobility services. They also received a free-to-use mobility budget of €300, which according to the ADAC, is slightly below the monthly costs of an average private car. After the cars were moved outside of the city the re-transformation process of the streets started. Based on interviews and field observation certain ideas were implemented as for example bicycle parking, urban gardening or free space for kids. After the research period, the parking space was cleared, the cars



returned to their initial place and the evaluation began (Digital Hub Mobility 2021).

#### Outcome

In the aftermath the key findings of the project were that everyday mobility didn't really change without a private car as public transport and bicycles were already the main modes of transport. Some issues occurred with day trips or weekend trips. Without a private car one is bound to public transport times and lacks flexibility or has to dispense extra needs like space for luggage or others. Also, the redesign of parking lots has not been of everyone's interest. For similar projects in the future, closer participation with local residents could increase the acceptance and awareness for such a project. Overall, 3 of the 8 households sold their car as they got to experience the unnecessariness of it (Digital Hub Mobility 2021).

#### Discussion

After the pilot test mentioned above the project was frozen as - without a business model - no financial means can be generated to finance the mobility budget and the redesign of the streets (Herzog 2021).





Figure 1.18: Repurposed parking space

#### Outlook

As the results of the project have shown, a car is – for some people – not necessary. But it needed UMPARKEN Schwabing to show them. It therefore would be great, if the city, companies and research groups could gather more financial means to keep doing research in the field of mobility budgets.

Munich - Urban Planning - 33

### **AUTOFREIE ALTSTADT**

Cars are the predominant mode of transport in Munich. Nevertheless, sustainable change is coming, and more and more locations are transformed into car-free or car-reduced places.

#### Augustenstraße

Right in the middle of the district Maxvorstadt one can find the Augustenstraße. Due to its location, it is very popular among cyclists and pedestrians but also cars.

In July 2021 the City of Munich decided to transform the street in favour of the more vulnerable groups. By decreasing the speed limit of 50km/h to 30km/h cyclists can safely change the too-small cycle path to the main road and thereby leave more space for the pedestrians. 25 parking spots are replaced by delivery zones. 45 other parking spots are taken away to offer more space to pedestrians and bicycle parking. In addition, trees shall be planted in the former parking spots. Due to the narrow prerequisites, the construction of a wider bicycle lane was not possible due to through passing bus traffic (Hertel 2021).

Critique came from the conservative party CSU. They do not want parking spots to be taken away from residents and also fear that cyclists could delay bus schedules (münchen.tv 2021).

#### Hauptbahnhof

The central station in Munich is currently under construction. The main site is due to the second main line that is being built to ease the public transport situation. After that, the main hall of the station is being rebuilt in a futuristic look. What is even more futuristic - at least for a city like Munich - is that the entire space in front of the building is going to be car free. Trams, taxis and buses are still going to be able to access the train station. Once again critique from the CSU - the conservative party, which still wants people to be able to drive their car to the train station (münchen.tv 2021).





STAKEHOLDERS



AFFECTED TRANSPORT Cyclists, Pedestrians, Public Transport (esp. Buses)

#### DURATION Ongoing

#### Tal

Tal is one of the central streets of the old town of Munich and - at the same time - one of the main trespassing roads for cars in the inner city. Though for the new concept "Autofreie Altstadt" the cars should be banned from the Tal and the street converted to a pedestrian zone. First drafts of the new concept have been dropped due to heavy critique from local residents. Once again, the biggest issues are the parking spots that would be taken away (Hinsche, 2021). The different concepts mainly differentiate in the use of space for parking, delivery zones, taxis or busses. One of the more extraordinary concepts was created by architect Markus Uhrig. He refers to the past of Munich and states that there were two rivers flowing through the Tal. In his concept the rivers would return to the inner city and the thereby created riverbanks would be connected by multiple small bridges (Billina, 2021).



Figure 1.19: Visualization of a new Altstadt redesign



SPACE



### **INZELL INITIATIVE**

The Inzell Initiative is a network of various actors and players in the field of mobility. It aims to develop and implement new concepts for better and more sustainable mobility in the metropolitan area of Munich.

#### **Motivation**

"Discuss traffic problems in the metropolitan area together and seek joint solutions aside the daily political disputes" was the main intention of Christian Ude, former mayor of Munich and BMW when they founded the cooperation in 1995. Back then they realised that sustainable mobility can only be achieved if all stakeholders politics, economics, administration and other sectors work together. The name of the initiative goes back to the location of the very first meeting – Inzell (Inzell Initiative 2019a).

#### How the Initiative Works

Until 2015 the initiative was split into smaller working groups that in a 2-3-year cycle all came together and presented their findings. After 2015 the organization was restructured and now consists of four main parts. The Inzell Steuerkreis is responsible for the main strategic direction of the initiative. Led by Dieter Reiter, current mayor of Munich, and Peter Schwarzenbauer, former board member of BMW, the Steuerkreis also defines fields of action in consideration of current traffic problems and the city's development goals. The Innovationszelle (Eng. innovation cell) is a cross-cutting project development group. Each of the cells has a specific field of action, a project manager and a team of relevant partners and stakeholders. In the Innovationszelle the Inzell-Projects are developed, shaped and implemented. The Dialogrunde which is held every year is a platform for the exchange of knowledge and information and there to connect the different stakeholders and partners of the Inzell initiative and beyond. Already in the 2000's first approaches towards developing and implementing traffic management as well as intensifying regional cooperation were taken. From 2010 on a stronger focus was laid on digitalization and smart cities combined with



the development of a regional shared strategy. While the Initiative was founded by two actors, it now consists of a network of 19 different companies, municipalities and associations (Inzell Initiative 2019b).

#### **Outcomes & Outlook**

Until today, the members and partners of the Inzell Initiative developed and implemented various projects throughout all transportation modes. The Parkraummangement for example is a concept to decrease the need for parking with the help of neighborhood parking only, car sharing or parking licenses. One of the largest projects is the Modellstadt 2030. The aim of this project is to develop a positive target vision for mobility and quality of life that should now be followed until the year 2030. This vision does not only apply to the inner City of Munich but also its metropolitan area. All the partners of the network were participating and working together for this project. Until 2030 it is planned to develop sub-projects to fulfill and reach the Modellstadt 2030 vision (Inzell Initiative 2019).

#### Discussion

Due to the large number of stakeholders from different fields the Inzell initiative has the potential to achieve great things for a sustainable future.

BMW	ADAC Südbayern e.V.	Bayerische Eisenbahngesellschaft GmbH	S-Bahn München GmbH
Deutsche Bahn Regio AG	Gemeinde Haar	Gemeinde Oberhaching	Gemeinde Petershausen
Green City e.V.	Handwerkskammer für München und Oberbayern	Landesverband des bayerischen Einzelhandels	Landkreis München
Münchner Verkehrs- und Tarifverbund (MVV)	Planungsverband Äußerer Wirt- schaftsraum München	Regierung von Oberbayern	S-Bahn München GmbH
Stadt Freising	Große Kreisstadt Germering	Stadtwerke München GmbH - MVG	

Table 1.2: Stakeholder Inzell Initiative





Figure 1.20: Inzell Initiative

Their past projects have been of great success. While in the past most of the projects were aimed to improve the situation for cars, they slowly but surely transform to a more holistic research group and use their knowledge for other modes as well.

### **CITY2SHARE**

City2Share is a union of 10 different partners that try to identify potential solutions for urban logistics, electric mobility and charging processes as well as autonomous driving and sharing concepts in Munich and Hamburg (city2share, n.d.).

#### Motivation

The main reason behind the research project is the dynamic growth in population that cities like Munich or Hamburg are facing and the resulting conflict about public space as well as the high in emissions. Therefore, the aims of the measures and concepts are to reduce emissions, equitable (re-)distribution of urban space, compatible organization of commercial and passenger traffic and to reduce private car ownership (Bauer et al. 2020). Throughout the inner cities of Munich and Hamburg, different projects were implemented.

The research project was funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety as part of the "Erneuerbar Mobil" program. The total funding costs summed up to €5.8 million (Pirner 2020).

#### Implementation

The project team consists of stakeholders of various backgrounds. After looking at various potential areas around Munich, Untersendling, Ludwigsvorstadt and Glockenbachviertel were selected as pilot areas due to their public transport access and infrastructural offers. City2Share consists of four subprojects that were implemented between 2016 and 2020 (Bauer et al. 2020).

#### Logistics in living quarters

In 2016 when the project was initiated the first step was to analyse the customer structures in the locations of Glockenbachviertel, Zenettiplatz and Sendling.

Businesses usually get more packages per day than private customers. Therefore, they are more profitable than others. The test fields are characterised by both - private households and



**STAKEHOLDERS** 

To store packages for a short period of time two containers were set up as micro depots in the areas. The high density of parking cars made the selection of possible locations difficult.

In July 2017 the pilot project went into operation with five employees, two regular cargo and two electric cargo bikes.

The micro depots are being picked up in the evening, refilled with new packages in larger logistic centres and returned to the area in the morning.

Due to early success, the staff number and the number of bicycles were extended to eight each during the Christmas period in 2017.

With the ongoing success of the project, another micro depot was put into operation. After the project phase ended UPS extended their bicycle delivery fleet to other guarters (Bauer et al. 2020).

#### (Electric) Mobility stations

The primary goal of the mobility stations was to offer (electric) alternatives to privately owned cars to ease the density of parking cars on the long haul. To promote how the future of inner cities could look like, the Zenettiplatz has been transformed into an attractive public space.

The mobility stations consist of multiple mobility elements.

One of them was the implementation of public pedelec bicycles into the MVG bike sharing system. These bikes could be rented and returned at the mobility stations. Unfortunately, they could only be rented at the mobility stations due to charging infrastructure there. By providing more bicycles and redesigning the return process in future mobility stations more users could be addressed.

The second part of the mobility stations were the information pillars, where information on





Technische Universität Dresden

Table 1.13: Stakeholder City2Share

mobility offers, current departure times of public transport and maps of the surrounding including restaurants and other POI's could be retrieved. For locations with a lot of arrivals and departures or with a lot of customers with no location knowledge these steles are the most practical.

One element that had great potential but was limited by the infrastructural prerequisites was the so-called Parkraumsensorik. Siemens provided radar sensors that are able to detect free parking spaces around the mobility station. With this technology, the number of cars looking for a parking space should have been decreased. Unfortunately, most of the existing power lines did not meet the requirements of the technology and therefore the Parkraumsensorik could only be implemented on a small scale at Zenettiplatz and Am Glockenbach.

The virtual mobility station in the form of the MVG more app was one central point of the mobility stations. Not only could one retrieve information on public transport schedules and

#### UPS

#### Siemens

#### DriveNow

current departure times but also use it to rent car-sharing vehicles and public bicycles or rent a taxi. An automated service called iPark Dienst was connecting car-sharing vehicles of DriveNow with the Parkraumsensorik. With this technology, the car could tell the customer if and how many free parking spots for car-sharing vehicles are in close proximity to the mobility stations. For people owning an electric vehicle, the app could also tell how many free charging stations there are at the mobility station. After City2Share the MVG kept this concept and implemented the M-Account, a single-sign-onaccount, for all MVG services.

The entire concept of mobility stations was developed in very close cooperation with the City of Munich and its relevant departments, the SWM, the MVG, district administration, taxi providers and many more. The implementation of a new car sharing law in the beginning of 2020 played a key role in the operation of the mobility stations. Until then privately-owned cars were parked at the car sharing parking spots. Due to the lack of the legal background not only were the parking spots then free of charge but the wrongly parked cars could not be avenged by local authorities (Bauer, et al. 2020).

#### Less parking cars in public space

Until 2018 the Zenettiplatz was only used as a public parking spot. In September of the same year a mobility station was implemented in the southern part while in the northern part the socalled "Piazza Zenetti" was installed and public space was returned to the local residents.

As part of the City2Share program the parking

spots were replaced by large furniture that invites people to rest there. By doing surveys and questionnaires and by inviting residents to commonly shape the place the Zenettiplatz was transformed into an inviting place of public space. Throughout the entire project period feedback and participation was a key element of the Piazza Zenetti. While the project was highly appreciated by many locals there were also three major critique points: fewer parking spots in an already stressed parking situation, gentrification of the already expensive district and the fear of the place becoming a loud and messy meeting point for difficult social grouping. Overall the advantages of it outweigh the negative thoughts of a small group of the local residents (Bauer, et al., 2020).

### Automated driving in a carsharing system

The fourth and last part of the mobility station program was the simulation of autonomous carsharing vehicles and their impact on car-sharing business and the environment.

The key to the success of free-floating carsharing systems is - besides the price - the spatial-temporal availability of vehicles. The advantage of autonomous cars is that customers no longer have to walk to the vehicle rather than have the vehicle come to the customer's location. Simulations and calculations based on booking data of 550 vehicles in the operational area of Munich found out that the ideal fleet size is between 150 and 200 vehicles. With this size, 95-99% of all requests could be fulfilled and that empty rides (e.g. on the way to the customer) only sum up to 10-13% of the total ride distance. This on the other hand has a positive impact on the costs. Not only could one autonomous car replace three to four regular car-sharing vehicles but also the price per minute could be reduced by a third.

Costs and the share of empty rides could be decreased even further if customers not only would do car-sharing but also ride-sharing or car-pooling with other customers.

The impact of electric autonomous car-sharing vehicles on the environment depends on many factors (e.g. how electricity is produced) or to what extent public space can be freed (Bauer et al. 2020).

#### Outcomes

In 2020, after the project was finished the evaluation process started. The key fields of action for the future that were identified are the following.

 Development and test of an innovative sharing system with autonomous electric



Figure 1.22: City2share: UPS station Am Glockenbach



Figure 1.21: Participation at the Zenettiplatz

vehicles and inductive charging

- Further development and optimization of bike and car sharing strategies with electric vehicles
- Use of innovative sensors and technologies to optimize urban traffic
- Environmentally friendly design of inner-city deliveries
- Redesign of living quarters in Munich and Hamburg including the development of multimodal mobility connections by using citizen participation (Pirner 2020)

### CHALLENGES

The City of Munich faces a number of challenges in the context of urban mobility:

#### Population Growth and Competition for Space

Munich's population is growing steadily. This development is due both to an increase in migration and to a surplus of births. According to current forecasts, the population will grow to 1.85 million people by 2040. This sustained growth, combined with an increase in the number of households and the growth in individual housing, is leading to competition for space (Landeshauptstadt München 2010, 2021d). At the same time, the number of registered cars has been rising steadily for years. Most of the time these cars are just parked, occupying much needed space. This space could be efficiently redesigned to contribute to a greener and more livable city (Landeshauptstadt München 2021f).

#### **Environmental & Health Protection**

Besides high energy consumption and increasing consumption needs in general, mobility in the city contributes significantly to a high carbon footprint. Even though today Munich residents make significantly more trips by bike or public transport and respectively drive less, overall, however, Munich's motorized individual transport increases due to the persistent population growth. This causes CO2 emissions to continue to rise. In addition to CO2 pollution, Munich's high traffic volumes and congestion also expose the city to high levels of air and noise pollution.

Besides being a contributor to climate change and environmental pollution, Munich residents will be affected by the resulting climatic changes. Munich has a high building and population density, making it particularly vulnerable to the rising temperatures caused by climate change. Heat will then be added to the already undesirable factors in the city such as dense housing development, heavy traffic, as well as air and noise pollution, which reduce people's quality of life. The already socially disadvantaged urban neighborhoods will feel the effects in particular (Landeshauptstadt München 2010). In contrast to previous plans, the city has now however set itself the goal of becoming climate-neutral by 2035 instead of 2050 (Landeshauptstadt München 2021f).

#### Attractive, safe, and socially just mobility

The aspect of safety is also important for a livable city and sustainable urban mobility. For example, the way to school and dangerous junctions for cyclists and pedestrians must be made safer. To achieve this, the city council adopted the "Vision Zero" in 2018, which aims to eliminate deaths and serious injuries in road traffic. This is an important yet ambitious goal that poses many challenges. To get there, the mobility system and infrastructure must be changed. In addition, it must be ensured that mobility is socially just. No one should be excluded because mobility offers are too expensive or parts of the city are simply inaccessible. Accordingly, mobility must not only be carbon neutral, but also attractive, safe and socially just (Landeshauptstadt München 2021e, 2021f).

#### Digitalization

Digitalization is comprehensively transforming our society and the mobility system. The effects of digitization will be felt in particular in areas such as mobility and energy supply. The expansion of new mobility options, and services such as e-mobility, autonomous driving, shared mobility, traffic control, space management, to name a few, requires well-developed digital systems and intelligent networking. The simplification of data collection, as well as the many new opportunities offered by sharing services and digital and integrated systems, represent a great opportunity for the future (Landeshauptstadt. München 2021f). Munich cannot afford to be left behind in this area but must play an active role in shaping it.

### CONCLUSION

Conclusively, it can be assessed that Munich is very much a city in transition with the challenge of turning the current status quo into a more livable, healthy and environmentally friendly future. There are a lot of projects planned or running with a majority focusing on individual transport. The car does take the leading role with cycling increasing in importance over recent years.

The "Inzell Initiative" is a key player to be mentioned, founded back in 1995 by the City of Munich and BMW with a holistic approach to creating mobility for the future, to enable change. BMW is a strong partner enabling, financing and initiating research and other projects that also brings a focus on the car as a mode of transport into the discussion. Projects like "Easyride" or "Tempus" focus on automated, connected and electric mobility, putting Munich on the map of important cities in the development of these technologies in Europe. The car as a mode of individual transport does play a leading role in these projects, alongside concepts like carsharing, autonomous shuttle busses and other means of ride pooling.

With cycling becoming more and more popular in Munich, it became evident that the city's urban design is very car-centric and not suited for cyclists. Two referendums voted for by the citizens of Munich, the "Radentscheid" and the "Altstadtradlring" were initiated and approved by the city council in 2019. Several measures to improve the cycling infrastructure and safety are part of these initiatives, including a cycling ring road around the oldtown of Munich. While all these projects have still to be initiated and not much has happened until now, they show the interest and motivation both politically and among the citizens for a change towards a bicycle friendly city. Adding to these projects is the political decision for a car-free oldtown in Munich, where first projects of redesigned streets and places that aim for a reduction of ban on cars can be found throughout the city. Here again it must be mentioned that Munich is only at the beginning of a transition.

The last important mode of transport in Munich is public transportation, having an extensive network of trains, metro, trams and busses running the city. Public transport in Munich is reaching its limits and the already well-established network increases the challenge of rolling out innovation on a large scale. Projects that are currently tested by the local provider MVG are among others an app for multi-modal mobility including all shared mobility offerings in the city or the "MVG Swipe+Ride" project that aims at dynamic and distance pricing for public transport in the city. Many European and German cities already have such systems in place which shows that Munich is lagging behind, but it also presents the opportunity to learn from others.

The City of Munich is Germany's economically strongest city right at the center of one of Europe's economically strongest regions. This position brings a lot of ambition to be at the forefront of mobility innovation in Europe, which can be observed across many players and projects active in Munich. The historic importance of the car as a mode of transportation as well as the strong local automotive economy presents both a challenge as well as an opportunity for the city. Despite many initiatives, as of now the City of Munich is still a car-centric city that does not allow much space for pedestrians and cyclists. Yet the initiatives established over recent years have shown that there is a will and motivation for change across many stakeholders in Munich, be it the citizens living in the city, politics, industry or research institutes.



SALTHOLM



# Copenhagen

Supervised by Carolin Zimmer

Kateryna Sihuta, B. Sc. Master's Program **Transportation Systems** 





Responsibility in Science, Engineering and Technology







## **COPENHAGEN, DENMARK**

The City of Copenhagen is known as the most bicycle-friendly city in the world (Madsen, 2020). With the Cycling Embassy of Denmark as a major contributor to the implementation of a diverse set of cycling solutions in Denmark, the country has a variety of stakeholders such as private consultants, bike manufacturers, municipalities, public organizations, non-governmental organizations, and others that are working together for improved cycling infrastructure (Cycling Embassy of Denmark, 2020a). In the year 2019 alone, the City of Copenhagen added 167 kilometres of new bike lanes to the regional bike path. Every day, 1.44 million kilometres are travelled by Copenhageners by bike and the construction of several new bicycle bridges is still ongoing (Madsen, 2020).

The City of Copenhagen urban mobility stakeholders also include EIT Urban Mobility Hub North (EIT Urban Mobility, 2020) and several projects by the CIVITAS Initiative, including CIVITAS Handshake or CIVITAS Create (Civitas Initiative, 2021). The Copenhagen Climate Adaption Plan focuses on the goal of a carbon-neutral Copenhagen by the year 2025. The main target areas here are mobility, pollution, and energy. Therefore, city and mobility planning faces a set of challenges but also possibilities for sustainable development in the city and implementation of innovative mobility projects (City of Copenhagen, 2011).

Copenhagen is not only a role model in cycling but also in urban planning and architecture. As the hometown of the famous architect and urban planner Jan Gehl, the city is strongly influenced by his projects and contributions, which can be seen throughout Copenhagen. Also, topics of cycling, walkability, and accessibility are influenced by this.

With BLOXHUB, the nordic hub for sustainable urbanization, Copenhagen established a new way of collaboration and partnerships for addressing the challenges of urbanization and climate change. This approach to co-creation also has a major impact on city planning and mobility projects, as the capital of Denmark shows (Bloxhub, 2021).



All entries refer to the year 2020 unless stated otherwise 💻

CO2-EMISSIONS

### 62K

GDP PER CAPITA (2019 USD)

### **78.2%**

### SHARE RENEWABLES ELECTRICITY MIX

DENMARK

### 38

### DAYS WITH LOW TRAFFIC

RANK 54 / 73

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RANK 1 / 20

### LOCATION ANALYSIS

Copenhagen is the capital city and the largest in Denmark. The city has a unique atmosphere providing a great number of opportunities for comfortable living. In order to better understand the reasons that make the city one of the most livable in the world, an overview of the City of Copenhagen is given.

#### Topography

Copenhagen is the capital city and the largest in Denmark. The city is situated on the east coast of the island of Zealand. Another small portion of the city is located on Amager Island. Copenhagen and Malmö (Sweden) are separated by the strait of Øresund which can be crossed by road or by train across the Øresund Bridge. (Danishnet.com, 2016). Mostly the territory of Greater Copenhagen is located on a relatively smooth, clayey moraine surface in the direction to the west. In the northern part, the landscape is getting hilly with alternating clay and sandy moraine. The central part of the city lays on a flat-arched hill reaching over 30m above sea level (Nielsen, 2013). The flat terrain surface and relatively small size of the city create a great precondition for cycling infrastructure.

#### Weather Conditions

The climate in Copenhagen is Baltic which is characterized by cold winters and mild to warm summers. Nevertheless, Copenhagen is located near the sea which makes the weather rainy, humid and often windy throughout the year. The coldest months usually relate from November till April, while warm weather is observed from June till September. Over the course of the year, the temperature typically varies from -2°C to 21°C and is rarely below -8°C or above 26°C. Moreover, the geographical location of Copenhagen determines the length of the day. During the winter months, the days are the shortest, while during the summer period the white nights can occur (Climates to travel, 2021).

#### Demographics

Copenhagen is the most densely populated city in Denmark with a constantly growing number of inhabitants and urbanization rate (World Urbanization Prospects, 2021). According to Copenhageners demographics, there are 73% of people of Danish origin, 8% are immigrants from Western nations and the rest 15% - from non-Western countries (World Population Review, 2021).

#### Government

The government of the City of Copenhagen consists of its supreme body, the city council followed by the seven standing committees. The city has an intermediate government system with divided administrative management. Such a system allows sharing responsibilities for the main city management between the Lord Mayor and the chairmen of the respective committee (the mayors). Sequential it grants the rights to the mayors to take the final decisions on the place reducing the number of cases handed over to the City (Municipality of Copenhagen, 2021).

There are seven responsible committees in the City of Copenhagen that manage the tasks relevant to their specific fields such as finance, culture and leisure, health care, social services, employment and integration, environmental, children, and youth committee. The Committees are governed by the established framework and tasks declared by the city council. Moreover, each committee has related administrations that are handling the questions regarding their specification (Municipality of Copenhagen, 2021).



Figure 2.3: Universities in Copenhagen

As the capital and the largest city in Denmark, The government process is ruled by the principles of democracy where all citizens can Copenhagen is the major financial centre in the take an active role in the city's life and country. The metropolitan area of Copenhagen development (Kobenhavns Kommune 2021). In creates around 40% of the overall country's order to improve the connection between GDP, attracts most foreign investment and is the citizens and administration, there is the Citizens largest centre in research and development Advice Service. Its main function is grounded in fields in Denmark. The city has a strong vision accepting and handling the complaints that are for green and sustainable development for coming from the citizens of the municipality, improving quality of life, economic growth and users and businesses. Based on the collected strengthening cooperation across municipal, regional and national borders, companies, the complaints, observations and information the Citizen Advice Service creates general public sector and educational institutions (The recommendations and initiatives for the Capital Region of Denmark, 2017). municipalities and administrations on how to improve or resolve the raising issues (Municipality of Copenhagen 2021a).

#### Economy

Being a small country Denmark shows a high standard of living and constant GDP growth (not considering Covid-19 impact). The country has an open economy that is mostly dependent on foreign trade (Nordea, 2021). Denmark's economy is historically based on service industries, trade, manufacturing, agriculture and fishing (Anderson, 2021). Due to the fact of limited natural resources, Denmark does not have many heavy industries, thus small enterprises ensure economic stability (Nordea, 2021).



Figure 2.4: Property value map

### **URBAN MOBILITY ANALYSIS**

In Copenhagen, about a third of all trips are covered by car. The second most important mobility option is the bike, with a share of about 29 %. Walking and public transport account for 19% and 18%, respectively. Trips to education and work are clearly dominated by cycling (41%) and public transport (30%), cars (24%) and walking (5%) play only a minor role (City of Copenhagen, 2017).

Multimodality

public transport stops.

Multimodality plays a major role in Copenhagen.

In the field of cycling, in particular, many efforts

are being made to link biking to other modes of

transport. Examples of this are the cycle

superhighways which are often located next to

other transport lines and options, the

integration of cycling in public transport, or

large-scale bike parking offers, especially at

#### Historical development

Since 1970, the number of bikes in Copenhagen has increased by a factor of 2.5, from about 100,000 to more than 250,000 bikes today. At the same time, the number of cars decreased from 350,000 to 250,000 today (City of Copenhagen, 2017). Until 1972, a tramway was operated in Copenhagen (Vognsyrer, 2018). From the 1960s on, Copenhagen suffered from high unemployment and a weak economy, which led to a significant reduction of inhabitants until the 1990s. To make the city more attractive, parts of the harbour districts were developed, and the created revenue was used to build new Metro lines. The first line was opened in 2002, in 2019 and 2020 the Metro network was extended to four lines, following the same financing principle (By of Havn, 2021).

#### Commuting

In Copenhagen, of 413,524 persons employed, about 19 % (80,159 people) commute 20 km or more to work (Danmarks Statistik, 2021).



Figure 2.7: Bicycle map

#### Public transport

Public transport in Copenhagen includes commuter trains, e.g., S-tog and Øresundståg, Mobility in Copenhagen is dominated by bicycle traffic. By 2025, at least 50 % of trips to work or the Metro, bus lines (A-bus for major routes, Seducation are made by bicycle. Furthermore, bus as fast lines, E-bus as express bus, N-bus there are five times more bicycles than cars in Copenhagen (City of Copenhagen, 2017). The for night lines), and the so-called harbour bus importance of cycling is also shown through a (havnebus), an urban ferry service. regulation, which states that four bike racks per 100 square meters new building have to be The S-tog connects the surrounding implemented(By of Havn, 2021). Through a municipalities with the city centre, the variety of actors, different measures have been Øresundståg connects Copenhagen with implemented in recent years to promote cycling Helsingør on the Danish side of the Oresund and in Copenhagen. Through this, it was possible to implement a common feeling of the cycling via the Oresund bridge with Malmö and Lund on the Swedish side. Some trains run even to more capital among the population (Cycling Embassy distant Swedish cities. The metro consists of of Denmark, 2020a). In addition, since 2015, the four lines, two major lines connecting the south city has ranked first in the Copenhagenize study, of the city and the airport to the western parts, which regularly determines the world's most via the city centre, and a newly built ring line in bike-friendly city (Madsen, 2020).

the centre with a connection to developed parts in the North Harbour. There are plans to expand the network (By of Havn, 2021). The busses connect all different parts of the city to interchange stations, and the harbour bus connects districts east of the harbour with the inner city.

Figure 2.5: Modal split 2007

Figure 2.6: Modal Split 2017

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#### Cycling

#### Walking

Walking plays an important role, especially in the city centre. In 2006, up to 80 % of the total traffic in the inner city was on foot (Villadsen, 2006). Most roads (except motorways) in Copenhagen have sidewalks, making it fairly easy and safe to walk in the city. Pedestrian crossings are often secured by traffic lights. For shopping, pedestrian traffic plays an important role, as pedestrians account for 23 % of the supermarket and street-level shop turnover (City of Copenhagen, 2017).



Figure 2.8: Cycle superhighways: Existing superhighways in orange, coming routes in grey, not yet financed routes in dotted grey and public bicycle pumps shown with orange markings

#### Private cars

In 2017, cars were used for about one-third of all trips in Copenhagen (City of Copenhagen, 2017). Currently, Copenhageners own 247 cars per 1,000 inhabitants while having a population of 613,319 (CIVITAS Handshake, 2021).

On several streets in the city centre, cars are being used less than bikes (Sorrel, 2016). Regulations for car parking changed significantly over the last few years. 30 years ago, for new buildings, the creation of one car parking spot per 100 square meters was required, by now builders are not allowed to build more than one parking spot per 250 square meters. New districts with well-developed metro connections are planned to be completely car-free (By of Havn, 2021). Noise from road traffic affects mostly residents along the motorways of Copenhagen. For the city centre, almost all roads are affected by noise, with huge differences between bigger and smaller roads (European Environment Agency, 2018).



Figure 2.9: Noise map. Purple: > 75 dB, dark red: 70 - 75 dB, red: 65 - 70 dB, orange: 60 - 65 dB, yellow: 55 - 65 dB



Figure 2.10: Copenhagen Metro map

## CHALLENGES

Around the world, Copenhagen is seen as a role model for livable cities and sustainable mobility. The city aims to be the first metropolis worldwide to be CO2 neutral by 2025. Accordingly, there is much to learn from the city. Nevertheless, Copenhagen has to deal with some challenges.

#### Rising car ownership

Even though Copenhagen is considered the bicycle city par excellence, the city is struggling with an increasing number of car owners. Between 2000 and 2014, car ownership increased by almost 30% (City of Copenhagen, 2016) leading to a rising proportion of trips made by car. While the share of trips made by care was 28% in 2006, it was 34% in 2016. Although this percentage of car ownership and use may seem low compared to other European cities, Copenhagen is accustomed to low car ownership and use. Accordingly, this increase leads to significant challenges in achieving the sustainability goals, maintaining and increasing the city's livability, or reducing congestion (Pucher and Buehler, 2021). For instance, the time spent in congestion in and out of the city centre is expected to increase by 149% from 2015 to 2030 (Boligministeriet, 2018).

The increase in car ownership is attributed on the one hand to the reduction of taxes on new car registration in 2016, and on the other hand to a steady increase in the income of Copenhageners. The combination of these two trends makes cars more affordable. However, the cars are not used for the commute to work, where cycling is easier and faster, but for recreational trips outside of Copenhagen, where the infrastructure is not as well developed. A rise in car ownership and car use increases the perceived level of stress and decreases the level of safety which eventually discourages cycling (Haustein et al., 2020; Pucher & Buehler, 2021). This would hit hard the City of Copenhagen and its cycling successes in recent years.

#### Bicycle parking & congestion

According to surveys, Copenhageners' satisfaction with bicycle parking was at 37% in 2016, which is relatively low compared to the municipality's goal of raising it to 70% by 2025. The low level of satisfaction is due to the fact that the high volume of cycling in Copenhagen's city centre is stretching the capacity of bike lanes and bike racks. This exacerbates the need to optimize the capacity of the cycling network and bicycle parking facilities (City of Copenhagen, 2018). Yet that's a tremendously complex task given Copenhagen's competitive urban space (Civitas Handshake, n.d.).





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### **INTEGRATION OF CYCLING IN PUBLIC TRANSPORT**

For a bicycle-friendly city like Copenhagen, the combination of cycling and public transport plays an important role. Measures like bike parking facilities at train stations and the possibility to take bikes on public transport free of charge improve the interaction of these modes of transportation.

#### Motivation

Mobility in Copenhagen is dominated by bikes, there are five times more bikes than cars in the city. In 2017, 41 % of all ways to work and education have been covered by bikes. Until 2025, the city aims to increase this share to 50 %. Simultaneously, Copenhagen intends to increase the cyclists' satisfaction and reduce the average travel times (City of Copenhagen, 2017). To achieve this goal, various measures have been taken, several of them improving the integration of cycling in public transportation.

#### Implementation

Copenhagen abolished any fees to transport bikes on most public trains and harbour busses, the transportation is allowed in all kinds of public transport, excluding trips during the rush hour, night busses, minibuses, and some specified bus lines (Din Offentlige Transport, 2021a). According to information from Din Offentlige Transport (DOT), Copenhagen's cooperation between the public transportation operators DSB, Movia and The Copenhagen Metro, also fees for transportation on public busses are planned to be eliminated, starting in 2021,.

Besides ticketing, also other measures to improve the togetherness of bicycles and public transportation have been taken (Din Offentlige Transport, 2021b; Movia, 2021). In the last years, several new metro stations have been opened. The exits of these stations are mostly located in former car streets, that are now transformed to dead-end streets for cars, only allowing bicycles to drive through. On the one hand, this allows bikes to take shortcuts compared to cars, on the other hand, space for bike parking is reserved (City of Copenhagen, 2021). At most metro and train stations, bike racks allow proper and safe stabling of bicycles,



AFFECTED TRANSPORT  $\square$ 



Bicycles, public transportation DURATION

in some cases even under weatherproof shelters. Busses are being retrofitted with bike racks and special spaces are reserved in trains. To improve the service on the last mile, important stations of the train and metro network are equipped with bike-sharing facilities in some cases even under weatherproof shelters. Busses are being retrofitted with bike racks and special spaces are reserved in trains. To improve the service on the last mile, important stations of the train and metro network are equipped with bike sharing facilities.

#### Outcomes

Due to the corona pandemic, also in Copenhagen passenger numbers in public transport significantly dropped (Din Offentlige Transport, 2021b). The impact of the innovations will become apparent as soon as the demand for mobility will reach pre-covid numbers.

#### Discussion

Better integration of cycling offers the chance to motivate a number of passengers to choose public transportation instead of private cars. Furthermore, improvements around the cycling infrastructure can foster multimodal travelling, e.g., cycling from home to a train station with a private bike, taking public transport to a station close to the destination and using a shared bike for the last mile to the final destination.

#### Outlook

As described, in the near future, more and more public busses will be retrofitted to carry bicycles, if the capacity utilisation allows (Movia, 2021).

Reduction of transport by cars and an increase in bike and public transport rides has the potential to lower emissions of air pollutants

#### SPACE

Transportation on the first and last mile can be improved and be less time-consuming



Figure 2.12: Storage spaces for bicycles in the S-tog

#### Applicability to Munich

Free transportation of bicycles in trains could also be an attractive measure in Munich, as it extends the range of destinations one can reach and might motivate commuters to use the bike notwithstanding fitful weather. Although there are already bike racks at most train and subway stations in Munich, improved bike parking facilities, e.g., with rain shelter, might increase the share of cyclists.



### **ELONROAD**

Elonroad is a Lund-based company developing a new kind of charging infrastructure for electric vehicles. It can be used both to charge vehicles while driving and while parking, giving the opportunity to reduce the weight of vehicles by allowing smaller battery sizes.

#### Motivation

Electric vehicles are playing an increasingly important role in mobility, especially in the urban context (Lienkamp et al., 2020; Riederle & Bernhart, 2021). The power supply is one of the greatest challenges for electric mobility, as charging stops are time-consuming and the range of vehicles is strictly limited by the battery size. Especially trucks and busses depend on heavy and spacious batteries, limiting the maximum capacity for goods and passengers. Moreover, charging stops are expensive because of high labour costs (Elonroad, 2019). Elonroad, therefore, develops a charging infrastructure embedded either in or on top of the street pavement, hence enables charging while driving. The same system can also be used to charge while parking (Elonroad, 2021).

#### Implementation

Technically, a conductive rail is mounted on or submerged in the pavement. Electricity is transferred to the vehicle via sliding contacts attached to the bottom, delivering up to 300kW. Power stations supply the electric rail every kilometre (Elonroad, 2021).

As part of the project EVolution Road, which is assessing electric roads for Trafikverket, the Swedish transportation authority, a short demonstration road has been implemented at Getingevägen in Lund in July 2020 and extended in March 2021 (EVolution Road, 2020, 2021). First and foremost, the project examines possibilities to electrify city busses, which are among the first test vehicles. In a second step, it also investigates possibilities to charge smaller logistic vehicles like light delivery trucks (Innovation Skåne, 2019). The demonstration road allows evaluating both, charging while driving with a rail mounted on



**STAKEHOLDERS** municipalities, government<u>s,</u> public transport operators, logistics firms, private car owners

### **AFFECTED TRANSPORT**

### Electric vehicles

#### DURATION 2019 - today

top of the pavement and in the pavement, as well as the charging in stationary traffic, in this case during the holding time at a bus stop (EVolution Road, 2020).

#### Outcomes

The demonstration road proves the feasibility of the technology. The cooperation with the local public bus operator Skånetrafiken can show potential for use within public transport systems.

#### Discussion

The system allows the electrification of urban vehicle fleets, especially for public transport, taxis, and delivery trucks, without trolley wires with its visual impairments and limitations to vehicle heights crossing the infrastructure. Furthermore, it allows different vehicle types to use the same infrastructure while reducing battery sizes and limiting charging times. According to Elonroad (2019), using their system for a bus system in a city could lead to financial break-even, the supply of further vehicles could create further revenue. For billing, a unique vehicle ID is registered by the rail, which is measuring the exact amount of transferred energy. The rail is connected to the car via Wi-Fi and linked to servers via the internet (Elonroad, 2019). Limitations to the technology could be the high investment costs in public spaces compared to private charging units and the pervasiveness of correspondingly equipped vehicles.

#### Outlook

In the future, the system is to be extended in Sweden and in Greater Copenhagen. Cooperations with public transport companies, logistic enterprises and municipalities could help to finance the system, leading to more suitable vehicles.

Through increased use of electric mobility, the urban air quality can increase due to a reduction of air pollutants as PM and nitrogen oxide



#### Applicability to Munich

The City of Munich aims to achieve its mobility plan MobiMUC, according to which by 2025 80% of all ways in the city should be covered by emission-free vehicles and public transport (City of Munich, 2020). Furthermore, the public bus operator in Munich, MVG, plans to electrify all public busses in Munich in the near future and use battery-powered tramways on a new tram line through the English Garden (MVG, 2019, 2020).

### **BATTERY HIGH-POWER CHARGING**

The high-power charger with an integrated battery buffer is an electricity supply solution for electric vehicles. It enables cost-effective high-power charging for vehicle owners and a low total cost of ownership for charge point operators, without the need for a powerful grid connection. (Nerve Smart Systems, 2021a)

#### Motivation

Decisive for the development of a batterybuffered high-power charger (B-HPC) was the effort to expand and improve the charging infrastructure for electric vehicles. The unwillingness of the users of motorised individual transport to purchase an electric vehicle (EV), which is founded on short driving ranges and long charging times of EVs, is intended to be reduced by the B-HPC system. In addition, the B-HPC was developed to be profitable for charging infrastructure operators (Nerve Smart Systems, 2021a). Also, bottleneck issues in the power grid can be avoided and energy storage can be made more efficient and profitable through this type of charging infrastructure (Nerve Smart Systems, 2021b).

#### Implementation

Fundamental to the implementation of the B-HPC was the development of a battery management system that enables variable topology in battery systems by micromanaging each individual battery cell. In 2017, Nerve Smart Systems developed a first variable topology battery system. In 2019, Nerve Smart Systems, OK, DTU & Fremsyn formed the TOPChargE consortium. Through funding from Innovation Fund Denmark and EUDP, the battery system was further developed into a high-power charger. The TOPChargE EUDP project started in January 2020. (Nerve Smart Systems, 2021d)

#### Outcomes

The onsite demonstration of the TOPChargE project was conducted in June 2021. The first high-power charger was installed together with a container-sized battery energy storage system in Rønne on the Danish island of Bornholm. The battery energy storage system



was connected to the local photovoltaic system at the site. Therefore, the electricity for fast charging can be generated sustainably (Nerve Smart Systems, 2021c). The implementation of the battery energy storage system with an integrated high-power charger allows EVs to be charged with up to 350kW, with the advantage of not loading peak demands on the power grid. This allows a range of 340 km to be achieved in 10 minutes of charging time. The ability of the battery energy storage system to control individual cells to charge or discharge the battery enables the technology to provide an improved charging infrastructure with the use of renewable energy. Also, the location of the B-HPC systems can be changed as needed.

The easily movable and modular design and low connection fees enable this to be realised guickly and cost-effectively. In addition, upscaling of the project's production and implementation is also possible (Nerve Smart Systems, 2021b).

#### Discussion

The battery high-power charging technology offers the possibility to charge EVs quickly and with renewable energy. Moreover, the battery energy storage system developed by Nerve Smart Systems makes it possible to implement the charging infrastructure in a cost-effective and flexible way. Finally, peak loads in the energy grid can be avoided and renewable energies can be better utilised.

The innovative charging infrastructure represents an important building block for the rapid and cost-effective expansion of a more sustainable fast-charging network. However, since the TOPChargE project is only conducting one onsite demonstration project, a more indepth evaluation of the technology is not possible. Nevertheless, it can be assumed that the B-HPC technology provides a sustainable solution for the decarbonisation of private motorised transport. Furthermore, political initiative is needed to set standards for the communication between charging infrastructure and EVs through legislation in





Figure 2.14: Battery energy storage system for the B-HPC on the island of Bornholm

order to guarantee the reliable use of the B-HPC technology for all customers (Nerve Smart Systems, 2021b).

#### Outlook

The upscaling of production and implementation is possible throughout Europe and even worldwide. As the TOPChargE project is still very young, the first systems will be installed in Europe to enable proper maintenance and operation.

#### Applicability to Munich

Due to the easily movable and modular design and the low investment costs, it is possible to install the technology also in Munich to improve the fast-charging network of the city and even the region.

Figure 2.15: High-power charger

### **URBAN CYCLING SOLUTIONS**

Copenhagen is known as the most bicycle-friendly city in the world. A comprehensive set of cycling solutions, developed by many different stakeholders in the City of Copenhagen and the country of Denmark, contributes to both increasing Copenhagen's cycling friendliness and making the knowledge available to other cities and interested actors.

#### **Motivation**

One of the main goals of the Danish Cyclists' Federation, a major stakeholder for cycling in Copenhagen and Denmark, is the promotion and integration of cycling in the everyday life of a community.

For this, it is essential to provide the same quality of infrastructure for cyclists as for car drivers. Through infrastructure measures, dialogues, and discussions, a mindset change should be achieved that enables the integration of cycling in everyday life. (Danish Cyclists' Federation, 2021)

#### Implementation

A variety of stakeholders are involved in the implementation of different cycling solutions. As early as the year 2000, the first concepts for cycling were published by The Danish Road Directorate. In 2018, the Cycling Embassy of Denmark developed an updated version with co-funding from the national Cycle Fund and the Union Cycliste Internationale (Cycling Embassy of Denmark, 2018).

The members of the Cycling Embassy of Denmark, which was established in 2009, range from private consultants and manufacturers to municipalities, public organizations, nongovernmental organizations and others. Together with all its members, the Cycling Embassy of Denmark aims to promote cycling and to transfer knowledge about cycling solutions. The fields in which the actors actively spread expertise are planning bike- and people-friendly cities, creating synergies between cycling and public transport, building safe infrastructures for cyclists such as bike lanes and bike bridges, developing successful campaigns that motivate people of all ages to cycle, designing urban furniture such as bike



pumps, bike parking facilities, and more (Cycling Embassy of Denmark, 2020b).

#### Outcomes

The Cycling Embassy of Denmark offers lectures, guided bike tours, masterclasses, and an extensive webpage with cycling solutions (Cycling Embassy of Denmark, 2020a). Many of these solutions have been analysed in more detail in the City of Copenhagen and are described here. For further solutions, the website of the Cycling Embassy of Denmark can be considered.

The solution of shared spaces relies on the fact that road users in an area decide together how to divide the space, without distributed priorities at intersections. In this way, the area is deregulated and different road users are not separated but integrated into the space together. The right balance between car drivers, cyclists, and pedestrians is crucial. This increases the common awareness, road users are more attentive, and the traffic flow is slower and more flexible. This type of road use works best with many light traffic users, dense urban areas with multiple functions throughout the day, and few parking facilities (Andersen, 2019c).

Large bicycle and pedestrian bridges are prominent examples of bicycle infrastructure in Copenhagen. They provide important links in the bicycle network, overcoming barriers such as major crossroads, railways, streams, wetlands, or canals. Moreover, compared to tunnels, such bridges are often a visual enrichment of the city, especially if they are architecturally appealing. They also contribute to the pleasant riding experience of cyclists through enjoyable views. Since such large projects often require a long planning period and a high budget, their usual time horizon for implementation is about 10 years. In addition, it must be determined who will use the bridge and in what form, whether a physical separation between bicycle and pedestrian traffic should be established, if stairs should be used for pedestrians, or how long and steep the slope should be. Moreover, the actual effect of such bridges is often difficult to predict using traffic models, as it often takes some observation time to consider new traffic habitats that have been created (Andersen, 2019a).

Cycle Superhighways are the solution for promoting bicycle travel that goes across and municipal borders (Cvcle bevond Superhighways, 2021). The main goal is to make cycling faster and easier to get more people on their bikes. The Cycle Superhighways are the second generation of bicycle lanes in Copenhagen and aim to shift medium distances of about 5 to 20 kilometres to the bicycle, which are otherwise covered by car. These cyclepaths often run along common transport routes and thus enable a smooth transfer to other means of travel, such as public transport. Also, the cycle highways are constantly being expanded and improved and are intended to be the most



direct and fastest route. This is made possible by green waves, even roadways, bicycle bridges and tunnels, countdown signals, bicycle pumps, service stations, improved lighting, wayfinding guidance, and a high level of operations and maintenance (Andersen, 2019b). So far, 30 municipalities are working together to implement the cycle superhighways project, which is a major coordination task (Cycle Superhighways, 2021). Therefore, in order to comply with the quality of the cycle paths, several objectives have been set up. The cycle paths should provide access to logical and direct routes between the home and the workplace or educational place. Also, good accessibility with the fastest cycling option between two areas should be guaranteed. Safety and security should be on a high level through the design of the Cycle Superhighways. Furthermore, the route between two areas should be highly comfortable and interesting experiences should take place during the ride. Examples for the application of this objective are hand and footrests at intersections, which make waiting and starting at traffic lights easier, or trash cans facing the cyclist, allowing waste to be disposed of while riding in a playful way. Additionally, the recognizability and identity of the Cycle Superhighways are important. Therefore, the routes are usually easily recognizable with the orange logo of the Cycle Superhighways (Andersen, 2019b). Also, investing in infrastructure projects like the Cycle Superhighways is economically viable as they are at least as profitable as large infrastructure projects (Andersen, 2019b). During the Covid-19 pandemic, the cycleways offered a flexible transport option and were used by a significantly larger number of people than before (Cycle Superhighways, 2021). However, due to the lack of scientific sources, it is not possible to clearly state the effects and reasons involved in the process.

be used tively by ing road avour of ng


Figure 2.16: Arm and footrest on a cycle superhighway for a comfortable stop at the intersection and the ability to push off with momentum when the light turns green.

Bicycle parking facilities are also among the highly important cycling solutions in Copenhagen. To ensure a good quality of bicycle storage they must be properly placed, comfortable, visible, secure and safe, and available. Moreover, good and organized parking facilities show cyclists that they are taken seriously. The design of the bicycle parking facility and its surroundings can and should contribute to a well-organised urban space and increased pedestrian accessibility (Røhl & Severinsen, 2019).

Information for cyclists and guidance is helpful and confirm the chosen route. The possibilities for wayfinding improvements are digital or printed maps, online route planners, directional signs, and dynamic signs. On the bike route, physical signs are the most common. These should be particularly designed for cyclists and adapted to the speed and distance. However, interactive signage can also be found increasingly in Copenhagen, which was the first city in the world to implement electronic displays just for cycling. Here, cyclists can be informed about road works or traffic jams on the route, for example. For larger construction projects, which require a detour of bicycle traffic, temporary signage for cycling is

necessary. With this, cyclists can be specifically informed and diverted (Niels Hoé, 2019).

In addition to sufficient bicycle infrastructure, additional smaller street furniture for bicyclists can also promote this active form of mobility. These elements are much more affordable to implement but make cycling easier and more enjoyable. In addition, they convey appreciation to the cyclists. Street furniture for bikers includes, for example, service stations, bicyclefriendly trash cans, or arm and foot parking facilities. Bicycle counters are also part of street furniture. These count cyclists at a location and show the number on a display. This can promote motivation for cycling, create a sense of community, or contribute to the city's data collection (Niels Hoé, 2019).

The Cycling Embassy of Denmark also offers other cycling solutions, for example in the areas of ITS, political leadership, children on bikes, financing and more, and therefore offers a perfect toolbox for improving cycling for cities and city planners.

#### Discussion

The cycling solutions of the Cycling Embassy of Denmark provide an integrated and detailed set of improvement options to strengthen cycling. The City of Copenhagen shows that investing in many different measures to improve cycling can have a big impact. A mindset change and inclusion of cycling in everyday mobility is clearly evident in Copenhagen. Other cities can also benefit greatly from the cycling solutions of the Cycling Embassy of Denmark. Also, it usually requires the implementation of a set of several measures that make cycling more accessible, attractive, comfortable, safer and faster.

#### Outlook

The City of Copenhagen will continue to work on improving the cycling infrastructure in order to remain at the top of the list of the world's most bicycle-friendly cities.



Figure 2.17: Five circles pedestrian and bicycle bridge

#### Applicability to Munich

In the City of Munich, solutions for improving cycling have already been partially implemented. However, it is urgently necessary to make active forms of mobility more attractive. A comprehensive set of different solution strategies would therefore be a suitable way to enhance the attractiveness of the City of Munich for cyclists and to benefit from a shift towards cycling in other areas as well. The currently running CIVITAS Handshake project can be an important first step in achieving this goal.

## NORDHAVNEN

Nordhavnen (North Harbour) has been the largest Scandinavian metropolitan development project for the last decades. The project was created within a masterplan for new city development in the old harbour area through sustainable and flexible guidelines of city planning (Cobe, n.d.).

#### **Motivation**

As a constantly growing metropolitan area of Copenhagen, Nordhavnen development project is considered for the next 40 years to provide homeplaces for 40,000 inhabitants and workplaces for another 40,000 people (Cobe, n.d.). From the old industrial port, Nordhavnen is being transformed to a modern multifunctional area providing leisure, businesses and flexible mobility options (Ariza, Ouintero & Alfaro, 2019).

#### Implementation

The agreement for Nordhavnen urban development was taken by the Danish government and the City of Copenhagen in 2007. The development of Nordhavnen area was conducted in a way of close dialogue with citizens, stakeholders and potential users of the district (By&Havn, n.d.). In 2008 the final competition was won by the Danish architects from COBE and their collaboration with Sleth, Polyform and Rambøll (Naidoo, 2010). The final plan contemplates a separation of the area into smaller islets divided by channels and basins. Thus, it allows the creation of independent districts that can be developed in several stages. The plan follows harbour and cultural legacy by keeping the existing buildings and industrial grid as a basic point for future development. Every separate islet is elaborated regarding the concept of a five-minute city where all the main activities and sustainable mobility options are available within a fiveminute walk from every corner of the island. Moreover, to provide connectivity around the whole neighbourhood the green Metro line and bicycle loop is going to be provided. The approach of a blue-green city allows to separate the industrial functions of the existing harbour and to create public spaces and recreational zones with an improved urban environment. In addition, Nordhavn is going to



### **STAKEHOLDERS**

Client: City of Copenhagen, Port Development; Architects: COBE, Sleth, Polyform and Rambøll

#### **AFFECTED TRANSPORT**



### Private cars

#### DURATION



first prize in competition 2008, on-going project, under construction

be an area with the robust aspects of the open city with towers and small family housing, shops, offices, sports grounds and cultural centres. Consequently, in that way Nordhavn is offering a place for everyone (Cobe, n.d.).

#### Outcomes

The first changes were made in the Århusgade district in Indre Nordhavnen where inhabitants and employees moved in 2014. Nowadays in the redeveloped neighbourhood Århusgade, there are cosy public spaces, harbour promenades, sports areas to fulfil the aim of a liveable city. Furthermore, due to the flexible trade policy initiative there are a variety of shops, cafes, supermarkets as well as commercial spaces and offices (By&Havn, n.d.).

On the 28th of March 2020, the new Metro station Orientkaj was opened which enabled fast connection to the city centre only within 9 minutes (Smith, 2020). A new station was designed as an elevated railway station located right to the harbour basin with respect to local terrain (Metro, n.d.).

#### Discussion

Indisputably redevelopment of Nordhavnen upscales the vision of future cities planning. Strongly concentrating on its core values in accordance with local prerequisites the new districts deservedly received DGNB's highest gold certification for sustainability (Ramboll, n.d.).

Nevertheless, there are several challenges that arise during sustainable urban development. Firstly, timing plays an important role in developing solutions and expert thoughts (Hvid, n.d.). Also, the balance between the elements should always be considered and the main task is to understand the interactions between the people and create enough space to fulfil everyone's needs regarding sustainability (Hansen, n.d.)



### SPACE

**Five-minutes city** design increases accessibility to any activity or point in the neighborhood in the fastest way



Figure 2.18: Badezone Sandkaj, Nordhavnen

### Outlook

While the project is on-going, there are going to be further extensions of the islets and developing areas regarding the project vision of sustainable development and in order to comply with the aspiring aim of the City of Copenhagen to become carbon neutral by 2025.

#### Applicability to Munich

According to the Munich city planning vision and Copenhagen's experience in creating livable cities, the City of Munich certainly could consider applying similar approaches while redeveloping existing neighborhoods or districts to upgrade the level of living, mobility and to face environmental changes in the longterm perspective.



### SANKT KJELDS SQUARE AND BRYGGERVANGEN

A major project to prevent rainstorm interference was conducted in Copenhagen. A heavily trafficked and previously unattractive area has become fully climate-adapted with biodiverse green areas for recreational activities (Danish design award 2020).

#### Motivation

Striving to the goal of being a carbon-neutral city by 2025 the City of Copenhagen makes a lot of efforts to make the city greener, more livable and adaptive to the future changes in climate (Lauritsen, D., H. 2015). The expansion of blue and green areas potentially prevents negative consequences of climate change as well as creates enjoyable places for people. Moreover, such tools are easily introduced at street level which makes it less expensive and more flexible than conventional intervention (Klimakvarter 2016).

#### Implementation

Sankt Kjelds Square used to be a large roundabout in the neighbourhood where many cars were driving too fast and thus it prevented the locals from usage of the green space in the middle of the square. Bryggervangen was a typical urban street with a lot of asphalt pavement, a lack of trees and flooded streets after heavy rains (Klimakvarter, 2016).

The new transforming project for Sankt Kjelds Square and Bryggervangen was developed by SLA Architects in 2016. It represents simple methods to effectively protect streets against cloudbursts and at the same time create green recreational public space and enhance biodiversity (Lila, n.d.).

The development of the project was conducted in close cooperation between the local groups of residents and architects to achieve the most suitable result for each side (Klimakvarter, 2016).

Incorporating the 586 new trees of 48 local species is the main idea of the project's rainwater management. Instead of leading the water away to the sewers, the delayed



STAKEHOLDERS SLA, City of Copenhagen, HOFOR, NIRAS, Via Trafik, Jens Rørbech, Ebbe Dalsgaard A/S **AFFECTED TRANSPORT** 

### Private cars

DURATION 2016 - 2019

rainwater in green areas gives life to the plants. The trees are planted in a specific way to form a network of green rain gardens to prevent streets from flooding and directly exceeding water to the port of Copenhagen via a pipeline network. Additionally, the walking paths and outdoor sitting places were integrated among new green areas to promote social activities and meetings for the local inhabitants (Lila, n.d.).

#### Outcomes

Through the nature-based design approach, the project has increased the neighbourhood's biodiversity, climate adaptive area and the quality of life of the residents. Furthermore, applied changes allowed to silence the existing traffic by narrowing the streets without reduction of parking spaces (Klimakvarter, 2016). In turn, it has led to noise and air pollution reduction while possibilities and comfortable places for social interaction were created.

#### Discussion

The redevelopment of the roundabout and the related area serves as evidence of an easy nature-based climate adaptation in the city. Founded on nature-based design practices, other projects in Copenhagen were conducted to transform streets and neighbourhoods with beneficial use both for citizens and natural diversity. Among those projects are Scandiagade transforming, Haralds plads, Kilvenaeldsparken, Tasingle plads, and Osterbrogade(Klimakvarter 2016).

#### Outlook

Urban nature plays an important role in the level of livability, attractivity and sustainability of Copenhagen. By bringing a simple solution, enhancing biodiversity on a street level, it gives a stable ground for green and climate-friendly development of the city as well as advantages for the citizens. Successful implementation of nature-based projects inspires not only Copenhagen for further transforming





Figure 2.19: Sankt Kjelds Square

frameworks but also other cities to implement similar concepts and measures in practice.

#### Applicability to Munich

Munich is constantly working on developing potential solutions to handle climate change and climate protection. The elaborating projects are considering the aspects of existing nature, landscape and possible options for upscaling the comfort level of the public spaces and the city overall. There are stakeholders which strongly contribute in evolving projects to create and redesign public spaces with respect to protect urban nature and enhance its diversity.

Copenhagen - Urban Planning - 73

### **BLOXHUB - HUB FOR SUS-TAINABLE URBANIZATION**

BLOXHUB is Copenhagen's innovation hub for sustainable urbanization that connects stakeholders from business, academia, government, and society. Since its foundation in 2016 they have attracted more than 300 renowned national and international members (BLOXHUB 2020).

#### **Motivation**

BLOXHUB was founded as a non-profit association by the Danish philanthropic organization Realdania, the City of Copenhagen, and the Ministry of Industry, Business and Financial Affairs (BLOXHUB, 2020; BLOXHUB, 2021c). Given that urban development encompasses so many different sectors and issues, and that holistic urban development can only come about through collaboration, the vision was to build an ecosystem for urban development. For this purpose, the impressive gathering place BLOX was built in the heart of Copenhagen providing space for BLOXHUB, the Danish Design Center and the Danish Architecture Center (BLOX, n.d.). Together with these two and more than 350 further national and international members - including Gehl Architects, the international city network C40 Cities, the Danish Ministry of Foreign Affairs, the City of Copenhagen, or university institutions and numerous startups, all of which work in the sustainable urban development context - the aim is to use cocreation practices to develop sustainable cities (BLOXHUB, 2021a).

#### Implementation

BLOXHUB's members are located in the fields of architecture, design, engineering, construction, facility management, or tech, to name a few. In doing so, BLOXHUB seeks to bring different perspectives together to make cities more sustainable. On the community's agenda are eight themes: Circular Economy, Design DNA, Digitalization, Governance, Livability, Buildings, Mobility, Resilience. The members of the ecosystem can meet and match in the co-working space or take advantage of different activities and programs, such as an accelerator program, a science forum or various workshops that aim to drive innovation in one of the themes (BLOXHUB,



**STAKEHOLDERS** 300+ renowned members from academia, business, politics, and society

#### AFFECTED TRANSPORT

Everything related to urban development

# Since 2016

2020; BLOXHUB, 2021c). The ultimate goal of BLOXHUB is for actors in the field of urban development to connect with beneficial collaboration partners. This requires expertise in networking and this is exactly where BLOXHUB is a pioneer (BLOXHUB, 2021).

#### **Outcomes & Discussion**

BLOXHUB aims to drive sustainable change in urban development. They see the topics of construction, mobility, circular economy, design, digitalization, governance, livability, and resilience not as separate from each other but as influencing each other, which is a prerequisite for a systemic transformation towards a more sustainable urban development. (BLOXHUB, 2020; BLOXHUB 2021c). With several programs and projects, BLOXHUB aims to drive sustainable change in the areas above. Among other things, BLOXHUB has organized a number of interesting events, including, for example, an ideation workshop about bicycle parking in Copenhagen. There they brought together actors such as the City of Copenhagen, Copenhagen Bike Community, Copenhagen Solutions Lab, Technical University of

Denmark, and other actors including start-ups and environmental protection consultancies. Besides that, BLOXHUB runs a laboratory for circular built environment, partners with the New European Bauhaus, offers an international matchmaking program for businesses, or organizes hackathons. Always with the goal to drive change collaboratively (BLOXHUB, 2021b; Irresistible Circular Society, 2021).

In summary, BLOXHUB is a huge ecosystem, with national and international members from business, politics, academia and society with ambitious and far-reaching goals. Nevertheless, they do face challenges such as conservatism in politics or in the building industry or a legislation in the built environment with many obstacles for investors. Nevertheless, or precisely because of this, BLOXHUB is trying to start a debate with those very stakeholders and join forces (BLOXHUB, 2021c).



Figure 2.20: BLOXHUB – located in the impressive building

### Outlook

BLOXHUB wants to continue to grow and make even more partnerships to push the topic further and further (BLOXHUB, 2021c).

#### Applicability to Munich

In Munich, a similar collaborative space was created with the opening of the Munich Urban Colab in 2021, which is already partnering with BLOXHUB (Munich Urban Colab, 2021). Munich has numerous players in the mobility sector. In addition to large corporations, innovative startups and excellent universities and research institutes, the city has important collaborations of civil society players who are strongly committed to sustainable and social urban design. It remains to be seen whether the Munich Urban Colab will succeed in efficiently linking these actors and contributing to a necessary systemic change.

### SMART CITY LIVING LABORATORIES

Copenhagen is known worldwide for Smart City solutions and laboratories. In our research, two living labs stood out in particular: First, Street Lab, a laboratory in the city center, managed by Copenhagen's incubator for smart city solutions, Copenhagen Solutions Lab. Second, DOLL Living Lab, the largest living lab for lighting and smart city solutions in Europe.

#### **Motivation**

Street Lab: Street Lab is managed by Copenhagen Solutions Lab, an incubator for smart city solutions governed by the City of Copenhagen that collaborates with partners from business and academia. It was founded in 2016 by Copenhagen Solutions Lab, Cisco, TDC, and Citelum. The laboratory covers 1 square kilometer in the heart of the city and includes two major streets. One is the inner city's busiest street, HC Andersens Boulevard, and the other is the traffic-calmed and pedestrianfriendly Vester Voldgade (The City of Copenhagen n.d.; Copenhagen Solutions Lab n.d.). The test area's concept is based on the "Copenhagen Connecting" plan, which has been awarded with the renowned World Smart Cities Award for the best Smart City project. (Jakobsen, K.H. 2014; Konieczek-Woger, M. and Naeth, A. 2020).

**DOLL Living Lab:** In 2014 the Danish Outdoor Living Lab (DOLL) was opened, Europe's largest living lab for intelligent lighting and Smart City solutions. Ever since the laboratory tests solutions on an industry park in the suburbs of Copenhagen with 12 kilometers of roads and bicycle lanes (Gate21 2016, DOLL Living Lab 2021a). Besides intelligent outdoor lighting solutions, DOLL Living Lab focuses on testing sensor-based waste management solutions, parking, traffic and mobility solutions, digital infrastructure solutions, environmental monitoring solutions, and more (DOLL Living Lab 2021b).

#### Implementation

**Street Lab:** Built by a collaboration of private and public actors, Street Lab seeks to implement smart city solutions in an interdisciplinary way. Based on needs identified in the municipality's departments, smart city ideas will be tested to meet those needs (Nordic Smart City Network n.d.). The



official innovation partnership was only scheduled for three years and expired in 2018. However, Street Lab continues to be used as a test area for smart city solutions. Companies and researchers are invited to apply with their smart city solution to test it in the living lab (Copenhagen Solutions Lab 2016, n.d.). **DOLL Living Lab:** The consortium behind DOLL is the regional partnership organization Gate 21, Danish Technical University (DTU) and the Municipality of Albertslund (Gate 21 2016). From the beginning on the goal was to establish a playground for intelligent lighting and Smart City solutions where manufacturers, public decision makers and knowledge institutions collaborate to create livable and sustainable communities (DOLL Living Lab 2021c).

#### Outcomes

**Street Lab:** Among the various smart city solutions, numerous sensors have been installed that measure diverse types of data. Parking sensors for example aim to facilitate quick parking to reduce traffic. Inconspicuous air pollution and noise monitors are deployed to measure atmospheric pollutants and decibel. Smart waste bins were installed to contribute

to efficient waste disposal. A smart watering system is being tested in preparation for there to one day be a smart central sewage system that detects leaks at an early stage. The data generated from Street Lab is shared with a range of open data initiatives around Denmark. To make efficient use of the data, the platform City Data Exchange was built for public-private data exchange. It provides companies, startups, universities, and public organizations with information about energy consumption, greenhouse gas footprints, or transportation behaviors (Shetty, V. 2016).

**DOLL Living Lab**: Seven years after opening, DOLL Living Lab has made some achievements in the areas of intelligent outdoor lighting, dynamic traffic light, smart waste management, environmental monitoring, and data infrastructure. As of today, the laboratory counts more than 50 national and international partners and more than 500 visiting organizations. It deploys and tests more than 800 networked IoT-devices, more than 20 IoTdevice management systems, and more than 80 outdoor lighting solutions from diverse providers, some of whom are depicted in the



three fields are

impacted. However,

the results are not

proof-based

SPACE

Through a variety of projects and real labs, all three fields are impacted. However, the results are not proof-based



Figure 2.21: Copenhagen Street Lab

Figure below (DOLL Living Lab 2021d). At the same time, DOLL is creating new partnerships and solutions in the areas of driverless busses, motion sensors or smart poles (DOLL Living Lab 2020).

#### **Discussion & Outlook**

The example of these two living labs shows a good attempt to test smart city solutions in public spaces and to involve a range of stakeholders. Around the world, Copenhagen is a role model for innovative smart city projects, which has been underpinned not least by awards such as the "World Smart Cities Award". In the area of Smart City and living labs, there is a lot to learn from the city.

#### Applicability to Munich

Living laboratories already exist in Munich as well. Theoretically, nothing prevents the implementation of living labs.





Figure 2.22: Solution Providers: Intelligent Outdoor Lighting

# CONCLUSION

The research on Copenhagen and the subsequent two-week research trip with almost 20 interviews with partners from business, academia, politics and interest groups and associations has provided an overview of the city's mobility system. A research visit to Copenhagen for urban planners and professionals working in the mobility sector is, therefore, a highly recommended experience.

Several implemented cycling solutions, such as Cycle Superhighways, bike parking, large bicycle bridges, wayfinding infrastructure, or street furniture for cyclists can be found in Copenhagen. The high quality of the cycling infrastructure and extensive effort by a large network of stakeholders made a mindset change towards a cycling city possible. In addition, the city is continuously working on optimising the transportation of bicycles on public transport. Copenhagen sees the improvement of the bicycle infrastructure not only closely intertwined with other mobility options but with its urban development as well. Following the principles of sustainable development, the City of Copenhagen is always concentrating on the implementation of superior projects for transforming neighbourhoods, districts and streets on a different scale. Nordhavnen is a new living district creating multifunctional areas with diverse public spaces, commercial areas and easy access to sustainable mobility options. Moreover, Copenhagen's Tree Policy often initiates redevelopment projects of the districts to increase biodiversity, to handle climate change effects and to improve livability in the city. The overarching goal of the city is to create a livable and sustainable city for people. In doing so, the capital of Denmark relies on collaborative action. With BLOXHUB, the Nordic Hub for sustainable urbanisation, the city has created a powerful ecosystem where more than 300 stakeholders from business, science, politics and society come together to shape the city's development. But not only that, numerous real labs are located in the city testing potential smart city solutions to help make the city more sustainable and vibrant. Technical solutions as well, play an important role in Copenhagen and the neighbouring city, Malmö. The project of the company Elonroad, for example, pursues an innovative and new approach of charging electric vehicles while driving or parking via charging infrastructure implemented in the road. After the first tests on public buses, a large-scale implementation for cars or trucks may be possible, which could significantly increase the attractiveness of electric vehicles due to smaller batteries and fewer possibilities to run out of range. Contrary to the Elonroad project, the battery buffered high-power charging technology by TOPChargE, offers an innovative approach to establish a high-quality charging infrastructure through improving existing charging points or implementing new improved ones. As it also offers the possibility to better utilise renewable energies, it can have a major impact on sustainable EV charging.

The projects analysed show that a wide range of actors in Copenhagen are dedicated to creating more innovative and sustainable urban mobility. However, strong commitment and further policy initiatives are still needed to achieve the goal of a carbon-neutral Copenhagen 2025.







# Oslo

Supervised by Daniel Schröder









# OSLO, NORWAY

Norway is known for its impressive fjords, strong economy, high Human Development Index, low crime rates, and as the country of electric vehicles (The Local 2016; UNDP 2020)

Oslo, the country's capital, is the most populous in the country and its municipality houses about one-third of the entire Norwegian population. Furthermore, it is among the fastest-growing major cities in Europe (Ghosh 2021). Considered a global city (GaWC 2020), Oslo is home to multiple companies in the maritime industry and houses many of the world's largest shipping companies. The city is the economic, cultural, and governmental center of the country. Additionally, it is among the most expensive and most livable cities in Europe (Martin 2018; Expatistan 2021).

Awarded the European Green Capital Award in 2019 (European Commission 2019), the City of Oslo has ambitious goals tackling climate change. Currently, the city strives to be fossil-free by 2030 (Oslo Kommune 2019) and carbon neutral by 2050 (European Commission 2019). Norway's unique location allows the country to produce electricity that is 98% from renewable energy sources, first and foremost from hydropower (Regjeringen 2016).

The low-carbon power production combined with a 54% share of newly registered vehicles being battery electric in 2020 (Elbil 2021) allows Norway to sustainably transition its individual transportation sector from combustion engines to electric motors. The increased share of electric vehicles is visibly noticeable in Oslo, where financial benefits played a substantial role, including tax breaks, toll reductions, and bus-lane access in the city (Elbil 2018).

However, a high share of electric vehicles does not address high levels of traffic in the city. Over the last years, citizens spent an average of 98 hours per year in rush-hour traffic, and there were only 35 days with low traffic, scoring worse than Munich, Amsterdam, and Copenhagen (TOMTOM 2020).

However, Oslo is focusing more on alternative modes of transport, including bikes and e-scooters. On the Copenhagenize Index, an index assessing bike-friendliness in cities, Oslo is considered a "rising star" and among the top ten cities worldwide, as, amid others, its commitment to bicycles in a hilly or snowy environment sets an example for other cities (Copenhagenize 2019a).

Further measures, for example, the 2015-2025 bicycle plan, promises to make Oslo increasingly bike-friendly in years to come. The car-free livability program from 2017-2019 removed many car parking possibilities in the inner city and gave way to space for increased city life. Innovative initiatives in urban transportation and strategic plans to tackle city traffic, CO2-emission, and further increase city livability together with accelerated population growth makes Norway's capital a city to watch.



All entries refer to the year 2020 unless stated otherwise



CO2-EMISSIONS

### 66K

GDP PER CAPITA (2019 USD)

### 98.8%

### SHARE RENEWABLES ELECTRICITY MIX NORWAY

### 35

### DAYS WITH LOW TRAFFIC

RANK 59 / 73

Oslo - Introduction - 85

# **LOCATION ANALYSIS**

Oslo is Norway's capital and is located in the south of the country (European Commission 2021). It is known for its wealth and great number of electric vehicles.

#### Geography & Climate

Water plays an essential role in Oslo's geography. The city is located in the northern bay of the 100 km long Oslofjord which includes 40 islands. 340 lakes are within city limits - the largest one, Maridalsvannet, also serves as the primary drinking water source (Statistics Norway 2021a).

The highest point of the Oslo region is Kirkeberget with 629 m (Oslo.com, 2021), and the total area of the City of Oslo sums up to 454 km<sup>2</sup> - 279 km<sup>2</sup> are forestry areas (Statistics Norway 2021a).

Norway's capital has a humid continental climate according to the Köppen & Geiger classification. The average temperatures vary between -5.1°C in January and 17.4°C in July, while the annual mean temperature is at 5.9°C. Regarding precipitation the maximum is reached in August (118 mm), while the minimum is in March (56 mm). The annual rainfall sums up to approximately 1010 mm which is almost the same as in Munich (Climate Data n.d.a, n.d.b)

Oslo and Nordic cities in general are known for the large differences in daylight throughout the year. In July the sun is up for almost 19 hours, while in December the time decreases to approximately six hours (WorldData 2021).

#### Socio-Demographics

In 2020, a total number of 5.4 million people were living in Norway, from which more than 80% are located in urban settlements. In 2021, the Oslo region had the most inhabitants (1,036,000) in Norway, while 696,000 people were living in the City of Oslo. Similar to Munich and other large cities in Europe, Oslo is experiencing an increasing population. Almost half of Oslo's residents are living in single households. 51 km<sup>2</sup>, the largest share of built up space, is used for residential purposes, while 37 km<sup>2</sup> are used for transport, telecommunication and technical infrastructure (Statistics Norway 2021a).

In Oslo, the largest age group are the 30-34 year

olds and 30% were born to immigrants or are immigrants themselves. The largest ethnic minority is Pakistani, followed by Sweden, Somalia and Poland. Statistics also show that in the western part of Norway the foreigner share is smaller than in the east. Oslogutt and Oslojente - men and women from Oslo - are less religious than the rest of the country (Statistics Norway 2021a). Only 63% belong to the Church of Norway (Evangelical Lutheran subgroup of Protestants Christianity) while the national average is at 82% (Statistics Norway 2020). The GDP per capita in Norway is at 634,532 NOK (approx. €62,000) while the average yearly earnings per capita sum up to 587,600 NOK (approx. €57,400)(Statistics Norway 2021a).

#### Oil, Energy & Economy

Norway's wealth, its sustainable mobility solutions in cities like Oslo and Bergen as well as its overall green image have their price. Natural gas and oil exports from 110 oil and gas fields are the main source of income of the Nordic country. In 2018, Norway extracted 84 million tons of oil and 118 billion m<sup>3</sup> of gas – more gas than Saudi Arabia or Algeria. Nevertheless, Norway invests in its infrastructure, subsidies for electric vehicles and other measures for a



Figure 3.3: Main Oslo universities

greener future of the country (Weichert 2020). Unfortunately, the common belief that almost 100% of energy used in Norway comes from renewable energies is not true as the Oslo Economics has found out only a few years ago (Oslo Economics 2018). But 93% of the electricity produced in 2019 derived from hydro power (Statistics Norway 2021b).

The city is characterized by its (maritime) trade and information technology companies. Electrical engineering, electronics and optical industry are the main branches of industry (Brockhaus Enzyklopädie 2021). The harbour of the capital is home to almost 2,000 companies such as shipping companies or shipbrokers, and has roughly 6,000 ship docking at the port from which 6 million tons of freight are transported to and from Oslo annually. Besides cargo load, over five million passengers use the harbor every year to get to different islands and countries or to arrive in Oslo. The service sector is the number one employment sector in Oslo with 59% of the jobs (Statistics Norway 2021a). According to the European Chamber, Norway is among the best European cities for business, right behind Denmark and Sweden (European Chamber 2020).

#### **Political System**

Norway's political system is a unitary constitutional monarchy with a parliamentary system of government. The head of the country is King Harald V (since 1991), while the head of the government is prime minister Erna Solberg (since 2013). According to the Democracy Index 2020, Norway in fact is the number one democracy worldwide (The Economist Intelligence Unit 2021). In the last elections the labour party (27.4%), the conservative party (25%) and the progress party (15.2%) were the three largest parties (Politico 2021).

Oslo is one of the 19 counties across Norway (Brockhaus Enzyklopädie 2021). In the latest city council elections from 2019, the conservative (25.4%), the labour party (20%) and the green party (15.3%) were the strongest parties - they hold most seats (36 out of 59) and form a governing coalition (Valgresultat 2019). Marianne Borgen is the current mayor (Oslo Kommune n.d.).

#### **Education & Research**

The level of education among Norwegian residents is fairly high. Approximately 35% of the population have a higher degree of education (three years of university education



Figure 3.4: Housing prices per square meter in Oslo

or more). In fact, more than 10% hold a masters degree (Statistics Norway 2019). The pupil to teacher ratio at primary schools in Norway is fairly low and has been decreasing to 11.6 in 2019 (Utdanningsdirektoratet 2019). In the same year the value was at 15.6 in Germany (Kultusministerkonferenz 2021). In secondary schools the ratio is even better with a value of 8.6.

Among all levels – starting with primary schools up to higher education at universities – the expenditures have increased every year (Utdanningsdirektoratet 2021). In Oslo there are 24 different universities and schools of higher education (Free Apply 2021). The largest one is the University of Oslo with 26,450 students enrolled in 2020 (Universitetet i Oslo 2020). 50 research institutes are based in Norway which focus on aquaculture across social sciences to computational engineering (Euraxess 2021).

# **URBAN MOBILITY ANALYSIS**

Oslo's mobility has several distinctive features such as the highest share of EV in the world and highest density of e-scooters in Europe. The city implemented successful public transportation and ticketing systems that facilitate ridership. By being a compact and walkable city, most journeys are short.

capita has been continuously reducing.

Between 1970 and 1980, the City of Oslo had

congestion problems on the central streets, but

introduction of E18 Fortress Tunnel and tolls

contributed to improvement in the city traffic.

Since 2014, the share of EVs has been steadily

Public transportation has significantly improved

after 2008 when Ruter, a joint regional public

transport company, was established. With Ruter, the ITS (Intelligent Transport System) was

introduced, which enabled digitalization of

public transport. Public transport has become

more energy efficient and environmentally

friendly. The City of Oslo has one of the largest

metros in Europe and commenced operations in

1898 (Global Mass Transit Report 2013). In 2016 it

was massively extended to ensure connectivity

to the city center. Since 1990, the toll ring has

constituted an important financing framework

for public transport investments. Since 2012,

the share of revenue allocated for public transport from toll rings has increased by 50%

increasing (IEC 2019; Xuewu et al. 2020).

#### Commuting

In the City of Oslo, daily trips under 1 km are taken mostly by foot, and under 3-5 km by foot and car. Longer trips are made by public transport and car. 90% of the population live within 300 meters of hourly (or more frequent) public transport services that are mostly used by commuters who travel to the city center (Tennøy, Øksenholt & Aarhaug 2014; IEC 2019).

#### Multimodality

Multimodality is achieved by a convenient ticketing system that is based on the distance (number of zones) travelled, not on the mode selected. Once the ticket is purchased, any mode combinations can be used to get to the destination, as long as they belong to the public transportation system. Implementation of the integrated modal scheme gave a noticeable rise in ridership in the City of Oslo (Rubin 2019).

#### History

Historically in the City of Oslo, the share of daily trips by car is decreasing and interchanged by public transport and foot trips. Car traffic per



(IEC 2019).

Figure 3.6: Modal Split 2019

#### Public Transport

Public transportation is the most popular mode in the City of Oslo counting more than 60% commuters for travelling to the city center (Tennøy, Øksenholt & Aarhaug The 2014). Public transport options in the City of Oslo include buses, metro, trams, ferries and commuter trains. The success of the City of Oslo's public transport system is more on how various modes are integrated and complement each other. The Metro has six lines that are built along the shore of Oslofjord through the downtown. The Metro network is integrated with the main city railheads, bus terminals and trams. Tram network complements metro and allows to get to the locations that are not served by metro (Rubin



served by metro (Rubin 2019). In the distribution of public transport modes, trams took the The city has one of the highest e-scooter highest share (IEC 2019). The integrated bus densities in Europe. In the last three months, network is collocated with the tram and metro the number of e-scooters has increased by stations (Rubin 2019). According to Oslo's almost 25% to over 25,000 according to the Urban Environment Agency. This market was Climate and Energy Strategy, all new city buses not regulated before July 2021. The ban on should be zero emission vehicles or use biogas by 2025. Commuter trains allow both long- and renting them between 11 p.m. and 5 a.m. as well short-distance journeys, which reduce pressure as general restriction on the number of eand congestion on other transport modes scooters available for renting have recently (Dixon, Herzig & Vollan 2019). been introduced in the City of Oslo (Modijefsky 2021).

The National transport plan has a strong focus on digitalization (Solvik-Olsen 2018). The City of Walking Oslo uses ITS (Intelligent Transport System) that greatly helps to reduce journey time and Walking is the third most popular type of congestion. Already today citizens use commuting in the City of Oslo, prevailing cycling smartphone-based ticketing systems that and standing behind only public transportation encompass all available modes of public and private cars. 28% of all daily trips were done transport and facilitate seamless travel by foot in recent years (IEC 2019). Today walking is continuously interchanged by commuting experience. Thanks to public-private collaborations, the City of Oslo actively tests with e-scooters (Karlsen & Fybri 2021). autonomous driving buses and, according to the Ministry of Transport and Communications, tests are now allowed without the presence of a driver (Dixon, Herzig& Vollan 2019).

### Cycling

Bike sharing is hosted by the program called City of Oslo Bysykkel, which installed over one hundred bike stations. Due to harsh weather conditions in winter, the program is only open from April till November (Rubin 2019). This is a popular service, with over 30,000 people using the bikes. To encourage cycling in a hilly city and long-distance trips the city introduced a support scheme for electrical bikes. However, compared to other modes of transportation, cycling is least popular, counting less than 10% (IÉC 2019).

#### **Private Cars**

Private cars are the second most popular mode of transportation in City of Oslo. Daily trips by car are especially popular with commuters who travel to the west, east and south of the city and least popular with commuters who travel to the city center. This is related to City of Oslo's recent incentives to free city center from cars, e.g. the number of parking spaces was reduced (Tennøy, Øksenholt & Aarhaug 2014; IEC 2019).

The City of Oslo is the world capital of electrical vehicles, with more than 35,000 EVs and plug-in hybrids. In 2019, there were more EVs than ICEs - 54,5% of the market. Since 2001, BEVs have been exempted from VAT (25%) and registration taxes. Additional daily usage savings that BEVs have compared to ICÉs are shown in table 1. As said by the Norwegian Ministry of Transport, EVs with two or more passengers have free access to public transport lanes. Also, in 2024 Oslo City Council will make an area inside the Ring 3 (see the map) accessible only for EVs. The

current Norwegian Government has decided to keep these incentives for all zero-emission cars until the end of 2021 (Tennøy, Øksenholt & Aarhaug 2014; Xuewu et al. 2020).

Current EV adoption is outpacing existing infrastructure (Dixon, Herzig & Vollan 2019), therefore, extension of the charging facilities takes the highest priority for the City Council. City rents car parking spaces during the night for local residents who have an EV. This takes place inside, e.g. the shopping centers' parking garages and the city covers charging costs (at least until 2022). This solves two problems in general. First, due to limited street space available for the charging infrastructure, where it competes with bicycle roads, this measure helps to relieve the demand on on-street public charging. Another reason is that over 60% of Oslo citizens live in apartments or townhouses in the City of Oslo (Xuewu et al. 2020). This means that these people cannot charge their EVs privately at home and depend on the public chargers' availability close to their apartment. Therefore, having a car parking garage equipped with a lot of charging stations allows residents to charge conveniently and for free.









Figure 3.8: Noise Map. Purple: > 75 dB, dark red: 70 - 75 dB, red: 65 - 70 dB, orange: 60 - 65 dB, yellow: 55 - 65 dB

Figure 3.9: Metro and Tram Maps Oslo

# CHALLENGES

#### **Population Growth**

Oslo's population is one of the fastest growing in Europe, with an increase of 30% since 2000 and another expected 30% increase in population by 2040. While this has spurred economic activity, it has placed increasing pressure on the environment and air quality and thus forced new thinking on how to plan and cater for environmental-friendly and less polluting mobility (Figg 2021).

#### Pollution

Road traffic is one of two largest sources of air pollution in Oslo today which emits particulate matter (PM2.5 and PM10) and nitrogen dioxide (NO2) – the latter of which is also influenced by ships and other harbour activities (IQAir 2019). Furthermore, in 2015 traffic caused about 60% of the city's carbon dioxide (CO2) emissions with almost 40% coming form privately owned cars (Figg 2021). In 2019 Oslo reached the target figure of less than 10 µg/m<sup>3</sup> which is recommended by the World Health Organization (WHO) (Sandelson 2017). However, the City Council generally aims at keeping local emissions well below health authorities' recommendations (IQAir 2019) and for this purpose implemented an action plan in 2018 improve air quality which includes measures such as an increase of cycle paths, improvement of public transportation and the transition to increasingly environmentally friendly vehicles in Oslo's Municipality (IQAir 2019).

#### **Population Density**

Correlated with the population growth, the increase in population density has been going on since the late 1980s (TØI 2009). Generally, Oslo is the top region by population density in Norway (Knoema n.d.). Between 2000 and 2009, within the urban area of Greater Oslo, the population density increased from 28.7 to 30.7 persons per hectare, while within the municipality of Oslo the population density increased by more than 11% - from 37.9 to 42.3 persons per hectare (TØI 2009).

#### Congestion

Since 2017 the congestion level has varied between 20% and 22%. While congestion levels in the morning and evening rush hours have decreased since 2019 by 16% and 9% each, in 2020 both still reached 35% and 49% (TOMTOM n.d.)





# PROJECTS

Public Mobility & Software Solutions
Autonomous Shuttles in Public Transport
Vehicle Technologies & Energy
Green Charge
Vulkan Charging Garage
Geofencing for Smart Urban Mobility
Active Mobility
The Oslo Cycling Strategy 2015-2025
Oslo City Bike
Urban Planning
Car-free Livability Program
Co-Creation
Nordig Edge

### AUTONOMOUS SHUTTLES IN PUBLIC TRANSPORT

Since 2019, Ruter – the public transport authority in Oslo – has been trialling self-driving vehicles as public transport services in the greater Oslo region and city center.

#### **Motivation**

Ruter believes self-driving vehicles to be an essential part in the future of mobility – therefore this public transport authority is testing self-driving vehicles to stay on top of technological developments and yield valuable knowledge that will help Ruter with providing improved mobility services in the future. This AV pilot project intends to introduce AVs to the general public in order to make first experiences, to explore the possible new mobility services self-driving vehicles provide, and to further the expertise in AV technology of road users and national authorities (Ruter 2020; TØI n.d.).

#### Implementation

So far, the tested self-driving vehicles or shuttles encompassed 4.75 m in length, 2.11 m in width and 2.65 m in height and could carry up to eight passengers, had a maximum speed of 18 km/h and a SAE (Society of Automotive Engineers) vehicle autonomy level of 3. The trial routes encompassed open roads with mixed traffic and intersections, area speed limits of 30 km/h, and lengths of 1.2 to 1.4 km (Ruter 2020).

Within this AV project, Ruter works in close cooperation with the Norwegian Centre for Transport Research (TØI) which studies each trial route in terms of customer and AV behaviour and interaction. TØI has so far focused on signal-controlled junctions in the Oslo city centre where cameras were installed which enabled TØI to video-analyse a total of 408 AV passages (Ruter 2020; TØI n.d.).

#### Outcomes

 $\mathsf{T} \ensuremath{\mathcal{B}}$  is analysis shows that the autonomous shuttles reacted correctly in most traffic



interactions, by recognizing violations of traffic rules and responding adequately and defensively by stopping. No severe conflicts were observed which is probably due to the AV's defensive driving style and low speed (Pokorny et al. 2021; TØI n.d.).

#### Discussion

The AV's defensive driving style often led to unjustified, hard and long stops - some of the stops were a reaction to cars that were parked alongside the streets, and to pedestrians crossing slightly outside the zebra crossing or standing near the crossing. These sudden stops led to other road users making risky manoeuvres in order to pass or overtake the shuttle which led to further hard stops by the latter. Furthermore, changes of traffic signals sometimes led to shuttles stopping hard or even "freezing" in the middle of intersections (Pokorny et al. 2021; TØI n.d.). These issues indicate that the autonomous technology might not be ready for mixed traffic yet or the need to improve this technology to not "overreact".

According to TØI, the Covid-19 pandemic provided another challenge by reducing the

numbers of expected passengers due to people's hesitancy to use public transport. Furthermore, some passengers were also disinterested in using the shuttles for being too slow and not going to the sought destinations. It appears that an increased speed and extended area of operation that meets users' demands would make self-driving public transport more attractive.

#### Outlook

The next phase of this self-driving project aims to investigate whether the offer of public AV's reduces the private car use in Oslo's region. For this purpose, the collaboration has expanded to include Toyota Motor Europe and the Finnish technology company Sensible 4. For this next phase, the offered AV's have a maximum vehicle speed of 30 km/h and initially follow a fixed route – the goal however is that the shuttle service will be transformed into a flexible booking service through which users can decide when and where they want to be picked up by the AV (Ruter 2020).



Figure 3.11: Autonomous shuttle in Oslo city center

#### Applicability to Munich

This AV project in Oslo takes place in mixed traffic areas that can also be found in the Munich city center and outer region. Therefore, in terms of project conditions and circumstances, trialling self-driving public transport could also take in place in Munich.

## **GREEN CHARGE**

Supported by the European Union, the GreenCharge project focuses on providing a charging infrastructure and a software solution that ensures smart charging for EV in the parking garage of the Røverkollen house cooperative. Smart charging implies meeting charging demands without grid-overloading and using local solar energy.

#### **Motivation**

#### **Charging infrastructure**

Based on the survey that was conducted on the early projects' stages, it was researched that for the residents, having their own charging point at their dedicated parking place is the prerequisite for buying an EV. However, their garage was not equipped with any charging points. EV owners were charging using 1 of 4 available shared semi-fast charges that were located outside of their garage. Residents had to charge their car before moving it back to its regular spot when fully charged - they found this very inconvenient. GreenCharge project's goal is to provide the required charging infrastructure for Røverkollen house cooperative so that residents can easily charge their EVs while parking in the garage (Søråsen et al. 2019a).

#### Grid reinforcement and peak fees

Electricity billing in Norway has recently changed from volumetric calculation basis to capacity based. This means that when grid capacity exceeds its limits due to increased demand, additional fees are implied (Xuewu et al. 2020). In this case, smart charging can help not to overload the grid and save money. SINTEF researched that with the expected number of EVs charging in a Røverkollen house cooperative's parking garage and the current capacity of the interconnected electricity grid, it will be impossible to meet demand of all inhabitants who have an EV. The grid would be overloaded, additional fees would be charged and charging at the parking spaces would only be possible after the grid reinforcement, which implies heavy investments. The goal of GreenCharge Oslo pilot is to avoid these fees and costly grid reinforcement while meeting drivers' charging needs (Søråsen et al. 2019a).



#### Solar Energy

Another goal of GreenCharge is to efficiently use the solar energy generated with the PV panels installed on the building blocks' rooftops. During peak hours, when many EVs are charging at the same time and the grid is reaching its limits, solar energy stored in a stationary battery can be used as a buffer to reduce the grid loading (Søråsen et al. 2019a).

#### Long charging

When many EVs are charging at the same time, especially in older buildings that have grid connection with the limited capacity, it causes an overloading problem (Søråsen et al. 2019a). Current market solutions such as LMS (load management system) prevent exceeding grid capacity by reducing the consumption of all connected EVs at the same time. Therefore, charging will take more time for all EVs. Contrarily, smart charging considers the individual charging demand of each driver and prioritizes charging for those who need an EV to be charged sooner, as SINTEF explained.

**V2G** 

V2Gimplies that an EV can not only charge but send energy back into the grid at the time of peak electricity demand. Therefore, EV can be used as an additional flexible resource being able to provide energy like a stationary battery. With smart charging, cars will be discharged according to the driver's needs, considering his next planned departure (Søråsen et al. 2019a).

#### Implementation

GreenCharge conducted a survey that helped to investigate the residents' charging needs. It was concluded that it is important for many respondents to have a charging possibility in their parking spots to consider a purchase of an EV. Also, it was observed that in two years 50% of the households will have an EV. Using the survey results, GreenCharge investigated if the charging demand of the projected number of EVs exceeds the current grid capacity (Søråsen et al. 2019b).

#### AIR The project implements charging infrastructure and enables zero emission EVs use and exploits local renewable solar generation

**SPACE** ΤΙΜΙ Residents have their own charging boxes, no need to wait until the Charging in the car charger is available. parking garage saves street space from the Also, with priority on-street charging charging option, car can be charged faster **Fun Fact** Almost 100% of the City of Oslo power supply is generated by renewable energy (98% - from hydropower, 1% from wind)(Xuewu et al. 2020)



Figure 3.12: Charging example

The core components of smart charging are cloud systems that are exchanging data every 15 minutes via API. Here are the main components and their functions (Søråsen et al. 2019b):

**EV-SYS** - EV in-vehicle system that collects through an app or display of the charging box the following data: SOC at arrival, SOC at departure, time of next departure and priority or flexible charging.

**CMS** - charge management system collects data from EV-SYS, meter readings from PV production, stationary battery, each charging point, and from other cooperative's meters. Collected data is further sent to NEMS.

**NEMS** - Neighbourhood Energy Management System receives data from CMS, from the grid as well as considers data about weather conditions. System analyses the received data and based on AI algorithms, forecasts consumption and schedules the charging of the different vehicles according to their expected future use and SOC, so as to exploit as far as possible locally produced renewable energy.

Schedule is sent back to CMS which starts to control charging (or discharging in case of V2G) of all connected Evs based on NEMS recommendations.

To develop the system components and features, various stakeholders are involved in the project.

Fortum Charge&Drive is Norwegian market leader in providing e-mobility solutions and has an eponymous mobile app that drivers use for charging their EVs. In this project, Fortum was responsible for CMS and the charging app. eSmart Systems is a software company that provides Al driven software solutions to the energy industry - they were responsible for NEMS. ZET is a software company that was responsible for NEMS and the charging app. SINTEF is an independent research institute that coordinates the data collection process. The City of Oslo coordinated the implementation of the pilot (Søråsen et al. 2019b).

As a pilot site, GreenCharge chose a house cooperative. The distinctive feature of this site is that all inhabitants have their own parking spot that is purchased together with a flat. All the 230 parking spots are located in the separate garage building, where the EV owners will charge in the future. GreenCharge aims to investigate how smart charging can help to reduce the loading of the interconnected grid with the limited capacity when substantial amounts of EVs are charging at the same time at the same place. House cooperative's garage complied with all these site's characteristics,

### **Deep Dive**

Electricity grid capacity is limited and often the grid is not able to install the power necessary for growing EVs charging demand. Moreover, when EVs are uncontrollably charged at the same time during the peak electricity consumption, it results in exceeding grid capacity and, consequently, in extra fees. This needlessly results in significant investment (€100-200 mio.) in new generation and network capacity that would operate only to serve this exacerbated peak (Xuewu et al. 2020). Smart charging implies data exchange between EVs, electricity grid, and local generation (e.g. PV) so to control the charging speed and meet both driver and grid needs.

i.e. dedicated place where EVs can charge simultaneously and which has local grid limitations, as SINTEF explains.

#### Outcomes

As SINTEF observed, the current grid capacity will not be enough for the projected number of



Figure 3.13: Charging example

EVs. Therefore, 64 charging points with varying causes the peak increase by 8% (405 kW), while speeds (1.8-7.2 kW) that support smart charging with smart charging this peak increase consists were installed in the garage. Chargers don't have of 5% (391 kW). As SINTEF explained, there is a a V2G feature yet. 70 kWp PVs were installed on possibility to reduce it to 0% if all Røverkollen the rooftop and a 50 kWh battery was installed. meters are configured differently from how they The mobile app that collects data from the are now. However, the Distribution System drivers was developed and released as well as Operator (DSO) is not interested in that since CMS and NEMS. All APIs between systems were they see potential losses for their business. established. According to SINTEF, the project has had a delay of 1.5 years and has started its At the current system set-up, users can choose testing phase just recently (July 2021). between priority charging and flexible charging Therefore, the effect from smart charging has options (Søråsen et al. 2019b), meaning that in not been defined yet (Søråsen et al. 2019b).

#### Discussion

As SINTEF explained, one of the main issues that contributed to the deferral were errors happening when Fortum sent optimal charging profiles to Schneider Electric's charging points. Instead of optimal power flow, each individual car acquired a minimum power flow, which made charging slow. Currently, the GreenCharge team has not found a reason but continues investigation.

During the project, some stakeholders did not deliver services that were agreed at the beginning since their business interests had changed, as SINTEF says. Therefore, roles and responsibilities had to be adjusted during the implementation phase. In the end, due to these issues, instead of using one universal mobile app for charging as it was planned at the beginning, drivers would need to use a separate app specifically for the home charging purpose. This might cause some difficulties for customers. During the further project development, it would be worthwhile to conduct an additional survey for the users to identify these difficulties.

V2G feature has not been implemented yet since there were no charging boxes supporting V2G available on the market when GreenCharge procured the charging points, as SINTEF says. Moreover, according to the current OEMs policies, drivers lose the car warranty if they participate in V2G (Søråsen et al. 2019b). Finally, there are not many car models on the market now that are technically able to support this technology. Despite these barriers, with the further advancement of V2G, market and policy around it, GreenCharge can make use of their project location, infrastructure and software to perform V2G tests using a test car in the future.

Current figures that SINTEF shared shows that without smart charging, charging of 70 EVs

At the current system set-up, users can choose between priority charging and flexible charging options (Søråsen et al. 2019b), meaning that in case of priority charging, maximum charging speed will be assigned to a car, while in case of flexible charging, speed will vary depending on the system's conditions. It is worth further investigating how users make their choice and how the system reacts if all users choose priority charging.

#### Outlook

As next steps, GreenCharge needs to make the project operable by solving the issue with the error previously mentioned. When the error is cleared, as SINTEF said, the next step is to gain knowledge from the testing phase. The results of smart charging effect on the grid expansion deferral, use of renewable energy from the local PV and user's acceptance will be estimated. They also plan to conduct an additional survey during the testing phase for drivers to estimate their attitude to the implemented solution.

#### Applicability to Munich

In the Munich metropolitan region, most people live in three or more dwelling buildings where charging facilities are less common than in, e.g. single dwelling buildings. In Germany, the shift in the type of dwelling from single dwelling buildings to more apartments decreases the availability of home charging and increases the need for public charging (Nicholas & Wappelhorst 2020). If the access to an individual charging point is important for citizens and facilitates their consideration of buying an EV, then, with the further EV penetration in Munich, the need in home charging facilities in the apartment blocks and in smart charging will increase, and GreenCharge can serve as reference for Munich.

# **VULKAN CHARGING GARAGE**

SEEV4-City is another project supported by the European Union that aims to implement more EVs charging facilities and smart charging. Compared to the GreenCharge project described before, SEEV4-City examines another use case: smart charging in a public parking garage near the Oslo city center.

#### Motivation

The SEEV4-City project has a similar motivation as the GreenCharge project which differs only in details primarily associated with the project use case.

#### Streets' space

SEEV4-City aimed to facilitate publicly available charging by not using the streets' space but a publicly available parking garage instead. This will allow cars to get away from the city streets on the one hand and utilize the capacity of the car parking garage better on the other hand (Xuewu et al. 2020).

#### **Charging Infrastructure**

As it was also researched in GreenCharge, the presence of available charging infrastructure can facilitate consideration of purchasing an EV and, consequently, decarbonization of the mobility sector. With 104 chargers to be installed in the car parking garage, the project aims to replace as many conventional vehicles as possible, shifting in the next few years from 400 to 1000 EVs. SEEV4-City expects the consequent CO2 emissions reduction of 90-120 tonnes/year (Xuewu et al. 2020).

#### Grid reinforcement and peak fees

As it was also observed in the GreenCharge project, SEEV4-City also implements smart charging to reduce the loading of the interconnected grid during peak hours and, consequently, defer costly grid investments and eliminate fees for exceeding grid capacity during peak hours. The goal is to reduce the peak to 20% (Xuewu et al. 2020).

V2G SEEV4-City also wants to include V2G to use additional flexible energy from EVs during



#### Implementation

As a project site, SEEV4-City chose the car parking garage called Vulkan near to the center of the City of Oslo. It contains 450 parking spaces and serves both residential and commercial (e.g. taxi, car rental companies) EVs. Vulkan estate is the mixed-use area of a large market hall (Mathallen), shops, restaurants and cafes, hotels, offices and private residences (Xuewu et al. 2020).

The SEEV4-City implementation approach is shown in the table below and reflects key differences with the GreenCharge project's approach.

The prominent difference in implementation with GreenCharge project is that users can choose the charging speed (3.7 kW, 7.2 kW, 11 kW and 22 kW), which can only be changed (reduced) by EMS if there is a peak and stationary storage cannot provide enough capacity. There is no NEMS that assigns charging speed for each car, like it was in GreenCharge. EMS distributes charging power according to the requested speeds among charging points (Xuewu et al. 2020).

Every 15 min EMS collects the following data:

- 1. Power imported from the grid
- 2. Battery exchange
- 3. Consumption of each charging station

If power imported from the grid exceeds preset threshold, EMS gives command to the stationary battery to discharge. If power imported from the grid is less than pre-set threshold, EMS gives command to the battery to charge from the grid (not from PV like it was in GreenCharge)(Xuewu et al. 2020).

SEEV4-City used KPI (key performance indicator) methodology to quantify the defined goals. There were 2 KPIs: CO2 emission savings and grid investment deferral (by peak demand reduction)(Xuewu et al. 2020).

CO2 emissions savings were calculated based





on the number of conventional vehicles (ICE) that are substituted by EVs charging at Vulkan parking garage. Calculation considered emissions of ICE and EV at their different lifecycle stages. This information was obtained by the literature review. SEEV4-City made an assumption that EV's battery is recycled at the end of EV's lifecycle and considered that in the City of Oslo ÉVs are charged with 100% renewable energy (hydropower and wind). To calculate the substitution number, SEEV4-City considered weighted average driving efficiency of Norwegian EVs, assuming that this will represent the EV charger usage at Vulkan. Knowing the average monthly energy charged through Vulkan's charging points, CO2 savings can be calculated (Xuewu et al. 2020).

To estimate grid investment deferral, SEEV4-City estimated peak demand reduction that can be achieved by implementing stationary storage that was meant to discharge during the peak loading of the grid. Peak demand reduction was calculated as follows: battery storage capacity (50.4 kW)/max peak demand value (Xuewu et al. 2020).

The project had three main stakeholders. The Oslo City Council was a lead project partner and investor of 50% of the project capital investment. Aspelin Ramm is the owner of Vulkan estate. Fortum Charge&Drive is the owner of charging points and Ferroamp EMS cloud platform that enables smart charging (Xuewu et al. 2020).

#### Outcomes

100 AC standard charging connectors and 4 DC rapid charging connectors were installed at the Vulkan parking garage. AC chargers are V2G-ready from December 2018, however real tests have not been conducted yet. DC chargers are not V2G-ready due to communication systems issues (Xuewu et al. 2020).

Project managed to significantly increase the use of EV charging infrastructure within the garage. This can be seen by the peak demand for EV charging: at the commencement of the project, it was 64.9 kW; in the end, it had risen to 378 kW (Xuewu et al. 2020).

EMS was launched in February 2017. Despite all chargers having flexible speeds, users cannot select the charging speed as it was planned. EMS assigns the highest charging speed for each car. In addition, according to Ferroamp's engineer, EMS's feature of reducing the charging speed of EVs when power is reaching grid's limit has not been implemented since there is still enough capacity margin and, therefore, feature is not needed yet (Xuewu et al. 2020).

A 50.4 kW stationary battery was installed in the

garage to reduce the peak loading. With the stationary battery implementation, the project could have achieved peak reduction and related to its grid investment deferral of 13%, but the battery did not discharge as it should have during the peak hours (Xuewu et al. 2020).

Project has exceeded the targeted CO2 emission savings, saving 912 tons/year compared to the projected 120 tons/year (Xuewu et al. 2020).

#### Discussion

There are several deviations from what was planned at the project commencement and the actual results.

First, it was observed that most of the time battery discharge was not synchronized with the peak hour and, therefore, electricity demand from the grid was not reduced during the peak hour. SEEV4-City explains it with the way the system was set up. If peak demand could have been reduced in a given month by stationary battery, that would have saved 7,500 NOK in that month. In addition, since 2019 the battery has lost part of its operation capacity due to human errors and a defected cell (Xuewu et al. 2020). Furthermore, the grid investment deferral calculations were not updated with the battery's reduced operation capacity which should make the resulting grid investment deferral lower. Finally, the project does not count battery capacity when estimating the year when grid investments will be needed. According to the report, at a given demand increase of 120 kW/ year, maximum grid capacity of 800 kW will be reached in the middle of 2023. However, when

considering battery operation capacity (not reduced) of 50.4 kW and the same demand increase of 120 kW/year, this figure will be reached only in the middle of 2025. It would be more illustrative if estimation of grid investment deferral was represented by the number of years rather than percentage of peak reduction.

Second deviation from the plan was that users cannot select the charging speed and EMS assigns the highest charging speed by default, although charging points have a flexible speed feature. Fortum Charge&Drive observed that it is too complex for the users to deal with a price model of differentiated fees for the different AC charging speeds (Xuewu et al. 2020). As a result, to simplify the user experience, the maximum charging speed was assigned for all users by default. However, this approach does not comply with the smart charging strategy. So far, the capacity of the interconnected grid can install even more EVs (Xuewu et al. 2020), but when the capacity is reached, assigning maximum charging speed for all cars will not be favorable. Therefore, if users put information about current and desired SOC as well as time of next planned departure (as it was done in GreenCharge) instead of choosing charging speed, that could solve the problem with grid capacity limits in the future.

In general, GreenCharge and SEEV4-City look similar in terms of technology implementation if in GreenCharge all residents choose priority charging instead of "flexible" option. In this respect, the maximum charging speed is assigned to all cars like in SEEV4-City. The only difference in this case is that GreenCharge uses local PV generation to charge stationary batteries.

Comparison Criteria	Local renewable generation	Charge point supports V2G	Use case	Type of charging points	Charging speed	Stationary battery	User data	Smart Charging System Components
Green Charge	Yes (PV on the rooftop)	No	Home charging	AC	Assigned by NEMS, 1,8 – 7,2 kW	Charged from PV, 50kW	SOC at arrival, SOC at departure, time of next departure, priority or flexible charging	Charging App, Charging point, EMS, NEMS, Stationary Battery, PV system, Grid
SEEV4-City	No	Yes (only AC chargers)	Public charging	AC and DC	Chosen by driver; AC: 3,7 kW, 7,2 kW, 11 kW and 22 kW; DC: 50 kW	Charged from the grid when there is a demand trough, 50,4kW	Charging speed (3.7 kW, 7.2 kW, 11 kW or 22 kW)	Charging App, Charging point, EMS (Ferroamp), Stationary Battery, Grid

Table 3.1: Key Project Differences



Figure 3.X: Variable speed AC charger in Vulkan parking garage

#### Outlook

SEEV4-City considers replacing faulty stationary battery modules and further analyzes the smart charging performance and evaluates the achieved improvements in the KPIs (Xuewu et al. 2020).

#### Applicability to Munich

Most of the citizens in the Munich metropolitan area live in flats in multi-dwelling houses. The availability of home charging in this type of accommodation is lower than in e.g. single dwelling houses, that are more common for nonmetropolitan areas. With the further EV market growth in Germany, the number of EV drivers without reliable home charging access, such as those living in apartments, will increase. These new consumers will be concentrated in metropolitan areas, creating a greater need for public charging than those in nonmetropolitan areas who more likely will have access to home charging (Nicholas & Wappelhorst 2020). Therefore, the demand on accessible and available public charging in Munich will grow. Installation of chargers in the parking zones of public places, e.g. shopping malls, can facilitate substitution of ICE cars to EVs, benefit visitors, local residents and reduce the demand on onstreet parking. At the same time, the need for smart charging will remain to relieve the cost pressure caused by upgrading grids (Bermejo et al. 2021) especially in the areas where a lot of EVs will be charging simultaneously (e.g. parking zones).

### GEOFENCING FOR SMART URBAN MOBILITY

The project Geofencing for Smart Urban Mobility (GeoSUM), led by Norwegian Public Roads Administration, focuses on creating a digital map of traffic conditions and alerting road users in a specific area. The pilot project has taken place in Oslo and Trondheim and was trialled with about 80 hybrid cars (SINTEF 2021).

### Motivation

GeoSUM's goal is to make car drivers drive more environmentally friendly and consciously. For this purpose, the technologies geofencing and C-ITS (cooperative intelligent transport systems) are combined: geofencing itself enables digitally mapping geographical zones, while C-ITS provides information about traffic such as accidents, schools as well as parking areas or fees which can be directly sent to cars within said zones through transmitter and receivers within the vehicles (SINTEF 2018; Rambæk 2021).

Furthermore, SINTEF examines how geofencing can help the efficiency, safety and environment of cities by qualitatively assessing whether digital alerts in cars can make car drivers drive slower and more environmentally friendly (Rambæk 2021).

#### Implementation

GeoSUM has so far been trialled through two geofencing applications: one trial focused on defining specific rules for a zone, such as the maximum speed in the area around schools, while the other specified low-emission zones where the vehicles themselves reported the relevant data within an area, such as the number of kilometers driven, to achieve fairer road pricing (SINTEF 2018). In order to test these applications, an alert system (a mobile screen and a transmitter that reads speed and fuel use) was installed in approx. 80 plug-in hybrid cars in Oslo and Trondheim, which notified drivers when their car approached a school or a low-emission zone - the drivers who opt out of fossil fuels received a financial reward (SINTEF 2021). Hybrid cars were picked as research objects because drivers can choose between fuels (Rambæk 2021).



Oslo was divided into three low-emission zones: an outer part, where the charge for driving with a petrol engine was 2 NOK/km, a middle and an inner zone, with NOK 4 and 6 respectively in charge per kilometer driven. At the start of the trials, all participants received an account with NOK 1000, so that every time they ran with gasoline in a low-emission zone, money was deducted. When the trial was over, participants received the remaining amount (Rambæk 2021).

#### Outcomes

Preliminary results show that drivers became more speed conscious and opted out of fossil fuels in the low-emissions zones and thus the proportion of electric driving increased. The alert system functioned as a reminder about the costs in different zones which motivated drivers to choose electric operation over gasoline (Rambæk 2021).

#### Discussion

The application of geofencing in traffic is new it represents a significant innovation, especially for road pricing and since it can be provided without any costly or rigid physical infrastructure. However, as with any smart application, securing the right to privacy however presents itself as a major challenge which could be dealt with solutions of privacy by design. With preliminary results that are internationally unique, these trails are presumed to have great value for traffic authorities and the car industry (SINTEF 2018; Rambæk 2021).

#### Outlook

In the next phase of GeoSUM, the participants will have screens integrated into the car instead of mounted on the dashboards. Researchers are also interested in testing a specially developed car which actively selects fuel in low-emission zones and helps the driver keep the speed limit. However, this car is so far only used in controlled tests (Rambæk 2021).

#### Applicability to Munich

In terms of hybrid cars, this geofencing



Figure 3.15: Phone with GeoSUM screen on car dashboard

notification technology could also be applied in Munich to motivate people to opt out of petrol. And in terms of all cars in Munich, this technology could remind drivers of specific traffic information or rules and motivate them to drive with lower speed or more consciously.

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### **THE OSLO CYCLING STRATEGY 2015-2025**

The Oslo cycling strategy (Oslo Sykkelstretegi) 2015-2025 is Oslo's plan to enhance and promote the mode of transport cycling. It focuses on the construction of bicycle paths rather than soft measures like education or advertisements (Haga & Lauritsen 2020).

#### **Motivation**

Oslo and Norway generally want to promote cycling. In the National Transport Plan (2014-2023) the country-wide mode share should increase to 8% (Norwegian Ministry of Transport and Communications 2013). In the latest National Travel Survey 2013/2014 the mode share was at 5%. The key areas to reach this goal are the cities of the Nordic country as distances are usually shorter and easier done by bike. Ideally, cycling share in cities averages between 10% and 20% (Hjorthol, Engebretsen & Uteng 2014). The promotion of cycling in Oslo is also part of the Storting's climate agreement and the municipal plan "Oslo towards 2030 -Smart - Green - Safe" (Oslo Kommune 2015).

#### Implementation

The Oslo cycling strategy consists of three main goals. The first one being the travel habits of the residents. In 2013, two years prior to the Oslo cycling strategy, the mode share of cycling was at only 8%. The aim is to raise that share to 16% by 2025. Considering the population growth of the capital, this comes down to three times more trips in absolute numbers. Subgoals of the main objective are for example 20% more business trips by bicycle or 90% mode share of walking and cycling on school trips by children. The second goal is based on the field of action of the bicycle strategy – the bicycle infrastructure. By 2025 it must be accessible, passable, and traffic safe. One of the sub-goals is that 80% of the inhabitants shall have less than 200 m from the cycle path network. The third and final goal is to make the inhabitants experience Oslo as a safe city to cycle. 40% of the inhabitants' experience Oslo as a good cycling city, 25% as a good city for children and elderly, and 30% as a safe cycling city. To reach these goals three focus areas are being tackled. The first one - the bicycle: a part of city life and urban space - tackles the integration of



**AFFECTED TRANSPORT**  $\Delta$ Private and public bicycles

### DURATION

2015-2025 (Phase I), 2025 < (Phase II)

Oslo, Spacescape & Markör

Cons., NPRA, Planning and

Building Agency, UEA, Ruter

bicycles in Oslo. Bicycles should be integrated into new development plans and during construction works cyclists should have as few but as safe detours as possible. For new buildings, bicycle parking is required and it was to discuss if showers and locker rooms for office buildings can be made mandatory. Intramodality is to be promoted by sufficient bicycle parking at terminals and it has to be investigated how bicycles can be taken on to public transport as for example in Copenhagen. The Oslo City Bike scheme will be expanded to up to 300 stations and almost 3,000 bicycles. In the second focus area, the cycle path network will be made denser. The distance that has to be covered to get from one bicycle path to a different one should not be longer than 800m (in 2015: 1780m on average). Cycling path design standards will be increased and cycling on the sidewalks next to pedestrians should not only be made forbidden but also unnecessary due to separate infrastructure. To identify paths, routes, and directions signage and markings should be redesigned and made clearer. To protect cyclists speed limits for cars at certain spots will be implemented, especially at intersections. Lastly, cycling should be allowed in both directions in one-way regulated streets wherever possible. The third and final focus

area concentrated on soft measures. The municipality of Oslo will introduce its own standards for bicycles facilities to become a cycling pioneer municipality. Companies can be certified and make their cycling-friendliness visible. In cooperation with supermarkets or other points of interest, bicycle parking should be placed close to the entrance of the facility. As cycling is different throughout the districts, every district administration should develop their own cycling-sub-plan. Oslo's schools and universities should encourage children and students to take the bike to school and campus. To promote cycling in general ad campaigns are run and to ensure good quality even outside Oslo, collaboration with other municipalities is key. Overall, 510km of bicycle network shall be built. The first half of it until 2025. The overall costs sum up to approx. 1.35 Billion Euro.

#### Outcomes

The concept and the goals of the strategy are working: the original mode share goal of 16% was replaced by the 25% goal. Already in 2023 64% of Oslo's residents will be in 200 m of the



Figure 3.16: Oslo bicycle path network before the bicycle strategy in 2014 on the left and how it is going to look like after the bicycle strategy

bicycle network (Haga & Lauritsen 2020).

#### Discussion

One critical point of the plan was failing to meet the deadline of when the entire 510 km were supposed to be built (Løken 2016).

#### Outlook

One could expect that the large investment costs will lead to good results. Political willpower and residents using the infrastructure complete the picture of Norway and Oslo becoming the rising star on the cycling horizon.

#### Applicability to Munich

A strategy plan as developed in Oslo with concrete measures and goals could and should be set up in Munich as well since so far Munich's plans have not been as fixed. Investing the same amount of money would be ideal but not necessary.

### **OSLO CITY BIKE**

Oslo City Bike is the station-based public bike sharing brand in the City of Oslo. It was completely refurbished in 2016 and enjoys a constantly increasing popularity.

#### Motivation

Over the last decades there have been many ways to share a bike in a city. Starting with freeaccess bikes in Amsterdam, to coin-based bikes in Copenhagen or station-based bicycles that can be accessed with a user card (Antoniades & Chrysanthou 2009). Oslo City Bike uses an app-based renting system. The entire system focuses - in comparison to most other bicycle sharing systems - on the effect it has and its efficiency. Data and prediction analysis are used to identify where, when and how bicycles are distributed in the system. That way more trips by bike and day are created which makes the use of hardware more efficient. Also, less truck rides are needed to re-distribute the bicycles across the stations (Skreiberg 2018).

#### Implementation

The backbone of Oslo's bike sharing system is its smartphone app which makes renting a bike very easy. After registering for the service, the app automatically detects whether the customer is next to a station and enables a "unlock button" in the app. Then a bike can be unlocked at the station and the smartphone screen tells the customer to pick up the bike from a certain bike rack. The customer just has to release the bike through pressing a physical button next to the bike lock and can shortly after take off. For returning the bike, it just needs to be pushed into the existing lock fastener at the station. The rental time is then automatically ended. Operating columns at each station allow bike access without a phone. In total there are more than 3,000 bicycles distributed at 250 stations that are spread across the operational area within Ring 3. During a ride the app also shows the duration and cost of the rental (Oslobysykkel n.d.a, n.d.b).



For every pass the first 60 minutes are free of charge. Áfter that 15 NOK (~€1.40) are charged for every 15 minutes. The maximum rental time is seven hours. Though, the average rental is 9:44 minutes (Oslobysykkel n.d.a, n.d.b).

Heydays, a Norwegian-based design studio, created not only the design of the bicycles and the Oslo City Bike identity. The idea is to emotionally connect the user to the bike sharing system. Its logo, the blue smiley face, is printed on every bicycle and looks at the user when opening the app. Depending on the weather or the availability of bicycles, the face changes its expression.

The owner of the city bike is a company called Urban Infrastructure Partner (UIP). With the introduction of the Oslo City Bike, the first milestone of the company was achieved. UIP plans, finances, and operates urban infrastructure in Oslo and other Norwegian cities. In partnership with Sporveien Media and Clear Channel Norway they also set up 200 new bus and tram stations with digital timetables. Over the past years UIP was rather successful as they tripled their turnover of 30 million NOK in 2016 to 87 million NOK in 2020 (UIP n.d.a, n.d.b).

#### Outcomes

In the first season the new bike sharing launched, more than two million trips were done around Oslo by 50,000 people. In 2018, the number increased to almost 2.8 million trips and the user number doubled to 100,000 users (UIP 2020). During the Covid-19 pandemic in 2020 the trip numbers dropped just below two million as less people had to travel to work (Oslo Bysykkel 2021).

#### Discussion

While Oslo City Bike is probably among the most efficient and user-friendly systems across the world, bikes can unfortunately only be rented between 5 a.m. and 1 p.m. At the same time, the entire bicycle fleet is usually only available from April to the end of November. Throughout the winter the fleet's number is reduced by two thirds - the remaining bikes are nevertheless modified and equipped with studded tires to make cycling in winter safer (Oslobysykkel n.d.a, n.d.b).





### Outlook

Oslo City Bike will presumably continue to be a great success, since Oslo will continue to make driving a car in the city, or at least its centre, unattractive. At the same time, the City of Oslo improves the situation for cyclists on a daily basis (see Oslo cycling strategy). With these prerequisites, local bike sharing can only become more successful.

#### Applicability to Munich

Renting a bicycle in Oslo is very fast forward and uncomplicated. As for MVG Bike, the public bike sharing system in Munich, a pin code is sent to the user's phone which has to be entered on a number pad on the bicycle in order to unlock it. As all the bicycles have a GPS sensor, the unlock system of Oslo City Bike standing next to a station and unlocking it by phone - could be implemented in Munich as well.

### **CAR-FREE LIVABILITY** PROGRAM

Oslo introduced the car-free livability program to tackle urban mobility issues in the city center. The goal was to make the city center more accessible and welcoming for all citizens. Multiple sub-projects included transforming carheavy areas, such as parking spots, into areas of public activity

#### Motivation

Privately-owned vehicles dominate Oslo's streets which leads to high levels of traffic and emissions in and around the city (TOMTOM n.d.). In addition to a high EV adoption rate (Elbil 2021), more measures must be implemented to reach Oslo's target of reducing CO2 emissions by 95% by 2030 (CNCA 2020), and the motivation to transform the city is not purely environmental. Increasing the attractiveness of the city center is a high priority of the government (Oslo 2020), and survey results show a desire for more pedestrian streets and cycle lanes, better maintenance and quality of streets and squares, and more green spaces (Oslo 2020). This includes improving the attractiveness of alternative modes of transport, e.g., bikes, e-scooters and reducing the impact of private vehicles in the city center.

#### Implementation

To achieve a well-integrated city center, everyday issues of citizens were assessed in the 'Public Space - Public Life' survey from 2012 to 2014 (Oslo 2019).

Freeing up space in the center was key to enable more city life and cycling and walking. Therefore, the city introduced six pilot projects in the city center to improve city life in 2017. One of these projects was the Fridtjof Nansens plass. Originally, this area was occupied by private vehicles, tourist buses, and parking spaces. Now, the streets are closed for private vehicles, and filled with newly installed furniture and activity areas.

Traffic reduction measures played a crucial role in enabling an improved urban environment and accessibility for all. Since this project was based on multiple programs, additional local collaborations were formed to achieve the



intended purpose. In general, the car-free livability program was a collaboration between public and private sectors.

#### Results

In 2019, after the projects were implemented, the city saw a reduction of city center traffic of 19% compared to 2018. Furthermore, the commuting routes were less frequently accessed by car, and the number of passengers per car rose from 1.41 to 1.85. Additionally, 14% more people were using the streets and 43% more people spent time in different urban areas in 2019 compared to the beginning of the program (Figgs 2021).

#### Discussion

Although the program intended to respect as many participants as possible, it did not remain uncriticized. Especially the car-heavy business district saw issues with the reduced access of private vehicles in combination with multiple construction sites. However, the elimination of 760 regular parking spaces is still relatively low compared to the remaining 9000 parking spaces in the inner city (Oslo 2019). In general, it is not clear if the measures of the livability program alone attributed to the reduction of inner-city traffic and the increase of time spent in the city and other city districts of citizens.

The Covid-19 pandemic saw a substantial reduction in inner-city traffic as most people worked from home during 2020 and the early stages of 2021. Even today, it is unclear how citizens will use mobility services or access the city center if working from home becomes a standard. This could make it more difficult to incorporate new projects to vitalize the city even further as it has become more difficult to assess the future.

#### Outlook

This program set the groundwork for multiple projects, including the "Action Plan for increased City Life" (2018 - 2027), "Area Zoning Plan for Streets and City Spaces in the Centre, "Get to know your city," and the "Platform for City Government Cooperation 2019–2023" (Oslo 2019). These projects will further increase the cooperation between the City of Oslo and its



Figure 3.18: Fridtjof Nansens plass with new urban furniture

citizens to prioritize city life quality for everyone while reducing the impact of private vehicles in the city.

#### Applicability to Munich

This project has relevance in Munich; the city suffers from heavy traffic. Results from a survey of current mobility and livability issues in Munich could set a framework for developing new areas of urban city life by removing certain parking spots in traffic-heavy streets. The results from Oslo are promising.

# NORDIC EDGE

Nordic Edge is Norway's official and non-profit innovation cluster on smart cities which aims to accelerate business development for more sustainable and resilient societies through co-creation and knowledge sharing between private companies, municipalities, and city administrations (Nordic Edge 2021a).

#### **Motivation**

With rapid urbanization comes increased pressure on infrastructure, climate, and services. Reaching the UN Sustainable Development Goals by the year 2030 requires comprehensive mobilization and change. Nordic Edge intends to be a "driving force for the development, testing and export of smart city technology and solutions (...)" (Nordic Edge 2021a) to create a new and large Norwegian export industry. Since Nordic Edge focuses on smart cities and their development, citizen involvement plays a major role in finding new solutions. Therefore, their slogan reads "Smart with a heart - From locally smart to global sustainability" (Nordic Edge 2021a).

#### Implementation

#### National Smart City Roadmap

One innovation project regarding smart cities involved the development of a National Smart City Roadmap. This roadmap follows one leading question: "How to improve the quality of life of citizens and contribute to greater business development without compromising on the environment and climate, as well as the opportunities and needs of future generations?" (Nordic Edge 2019). To approach this question, smart cities and communities should share these six visions:

Attractive, inclusive, effective, climate-friendly, resilient, and promoting health

At the same time, eight principles for smart and sustainable cities and communities have been developed:

Place people in the center, consider the bigger picture, prioritize climate and environment, promote inclusion and co-creation, focus on



next generation business, share, and use open data, develop competencies, and embrace change, act local and think global.

The roadmap is primarily targeted at the local and regional authorities since they are the drivers and facilitators for achieving the goals. Academics, Organizations, and business professionals are the secondary target group. The roadmap is not intended to be a competition nor a replacement for local or regional strategy plans, but as a guide that can be implemented into existing projects (Nordic Edge 2019).

#### Innoasis (Innovation Oasis)

Nordic Edge Innoasis is a co-working space in Stavanger, Norway, intended to take ideas to an international market by enabling an interdisciplinary work environment (Nordic Edge 2021b).

The tenants are a customized group of corporations, academia, public sector officials, and the start-up community to develop a dynamic location for networking to "drive business development and societal change" (Nordic Edge 2021c).

#### Nordic Edge Expo & Conference

Established in 2015, Nordic Edge Expo & Conference is a meeting place that provides a framework for bringing industry and academia together to exchange ideas on how to shape the future of mobility in cities (Nordic Edge 2021d).

#### Outcomes

After the launch of the roadmap, a needs-driven challenges competition was initiated to test its practicability. Through a two-stage process, 19 municipalities and counties submitted their challenges regarding sustainable urban development and over 150 stakeholders from the private sector took part in workshops. In June 2020, six finalists started to implement their solutions (Nordic Edge 2021e).

Innoasis is currently finalizing its trial phase and will fully open fall of 2021 (Nordic Edge 2021c).





Figure 3.19: Render of the Innoasis building

#### Discussion

The Nation Smart City Roadmap does not come without challenges. Generally, the amount of involvement, resources, and communication between and of local authorities will pose a challenge when introducing new areas of focus for project developments. Furthermore, the willingness to accept risks and change could present a hurdle.

Innoasis will need to prove efficient for interdisciplinary workspaces as covid-19 measures pushed people to work from home and embracing an online-focused workspace.

#### Outlook

The National Smart City Roadmap acts as a foundation for a larger-scale roadmap, the Nordic Smart City Roadmap. The goal of this roadmap is to "strengthen the Nordic brand as a leading smart city region, as frontrunners for a people-centered smart city model" (Nordic Edge 2021f).

#### Applicability to Munich

Insights from Innoasis could help shape the usage and efficiency of the Munich Urban Colab, which is a co-working space for urban mobility in Munich. Furthermore, the Nordic Edge Expo & Conference could act as an inspiration for future implementations of the IAA, which focuses more on mobility for the first time and is held in Munich in 2021.

# CONCLUSION

Norway's capital faces many modern-day urbanization challenges, first and foremost the test of accommodating an increasing population while reducing the impact on the environment. To add to this challenge, Oslo is amongst the fastest-growing cities in Europe (Ghosh 2021) and one of the most expensive worldwide (Martin 2018).

To combat the environmental issue, the City of Oslo must prove efficiency in implementing new and innovative measures to tackle local emissions. And Oslo delivers: Awarded the European Green Capital Award in 2019 (European Commission 2019) the capital is pursuing extensive reshaping of its transportation structure to make public transportation and active mobility more attractive. According to the Copenhagenize Index, an index assessing bike-friendliness in cities, Oslo is considered a "rising star" (Copenhagenize 2019) since its bike strategy to create a denser, more accessible, and safer cycling infrastructure has exceeded initial milestones (see Oslo cycling strategy). With multiple publicly available bikes (see Oslo city bike) and a high density of e-scooters, last-mile commutes are becoming increasingly attractive and accessible.

Nevertheless, a large share of commuters uses private vehicles, impacting the environment most significantly of all modes of urban transport. Hours lost in rush-hour traffic is the highest of all cities assessed in this report, as well as the lowest number of days with low traffic (TOMTOM 2020). However, Oslo is taking steps to help reduce local emissions by making electric vehicles financially more attractive than traditional combustion engines. Extensive tax and toll road reductions, prioritized parking, and bus lane usage enabled the share of newly registered BEVs to surpass the 50% mark in 2020 (Elbil 2021), manifesting Norway as the capital of electric vehicles. Renewable energy sources, most significantly hydropower, generate >98% of electricity in Norway (Regjeringen 2016), which further reduces the impact of EVs on the environment. Smart urban mobility projects like geofencing special inner-city zones promise to make drivers more conscious towards speed and fuel type (see the Geofencing project), while smart charging technologies assure a controllable impact on the power grid by managing the charging speed and time of charging of EVs (see GreenCharge project). Ruter, Oslo's primary public transportation provider, is testing the acceptance and feasibility of autonomous shuttles in everyday life (see AV shuttles project).

Tackling inner-city traffic, the city initiated the car-free livability program in 2017 to reduce the number of public parking possibilities and increase public spaces for more city life and citizen interaction. Results of this program are visible throughout the city with central spaces now housing new urban furniture and fewer cars; however, changes were not welcomed by everyone since private vehicle access to the inner city was reduced (see livability program).

Communication between different parties is essential when combating new challenges in urban spaces. Nordic Edge Expo, part of Norway's official innovation cluster Nordic Edge, provides a platform for companies to exchange ideas. Even though the headquarter is not located in Oslo but Stavanger, the impact of the innovation cluster extends beyond Stavanger's city limits. For example, the National Smart City Roadmap offers a framework for cities to improve the quality of life in the city (see Nordic Edge), which can be applied to Oslo.

Oslo's goals to reduce car traffic by one-third by 2030, compared to 2015, ban new fossil fuel-driven vehicles by 2025, and reduce 95% of CO2 emissions by 2030 are ambitious. Private vehicles own a large portion of the roads and covid-19 decreased the number of passengers traveling by public transport to an all-time low. However, current projects and measures promise to maintain the high adoption rate of EVs and boost the attractiveness of alternative modes of transportation while pursuing a lower impact on the environment. The urbanization challenge will require perseverance and commitment but based on the projects and goals of Norway's capital, it has the confidence to take it on.







# Amsterdam

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### AMSTERDAM, THE NETHERLANDS

Amsterdam - the capital of the Netherlands is not only known for its unique canals and hordes of tourists but is also considered a showcase city in terms of cycling: the bicycle is the first-choice mode of transport. It is used by thousands of locals every day, requiring innovations in the cycling infrastructure with bike-friendly intersection designs and bike parking solutions.

Home to central mobility institutions such as the EIT Urban Mobility Hub, the Amsterdam Institute for Advanced Metropolitan Solutions (AMS), the City Innovation Office of the municipality, or the Cycling Institute, Amsterdam is also the scene of numerous mobility initiatives and projects concerning all modes of mobility:

Apart from street experiments to the new North-South-Metro line with socio-ecological research, innovative crowd management, car-free neighborhoods, and Marineterrein - a living lab for testing the latest mobility technology - Amsterdam also has a sprouting start-up scene in the mobility sector.

Besides, Amsterdam is considered one of the pioneers in Europe in terms of electromobility: The city has one of the highest densities of charging stations in Europe, an electric taxi fleet at Schiphol Airport, and ambitious emission plans – due to the Clean Air Action Plan launched already two years ago, Amsterdam wants to become emission-free within its built-up area by 2030 for all forms of transport.

Because of this diversity of mobility-related innovations, Amsterdam has turned out to be the optimal place for the mobility benchmark - apart from the advantage of being able to communicate easily with English. Compared to Munich, similar population density creates comparability and provides optimal conditions for adapting innovative approaches from Amsterdam to Munich.



All entries refer to the year 2020 unless stated otherwise

**4.5MT** CO2-EMISSIONS

# 72.6K

GDP PER CAPITA (2019 USD)

### 25.2%

### SHARE RENEWABLES ELECTRICITY MIX NETHERLANDS 2020

### 44

### DAYS WITH LOW TRAFFIC

RANK 50 / 73

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# LOCATION ANALYSIS

The Dutch capital with its famous waterways - the Grachten - is not only the Dutch city with the most visitors per year, but is also known as economic and cultural center of the Netherlands.

#### Topography

Amsterdam was founded at the Amstel River, which was dammed to control flooding. The city has more than 100 km of canals, most of them navigable by boat. They are fed by the Amstel River and eventually terminate in the IJ (Brown & Benoist 2019).

Parts of the city lie below sea level, some of them on land that has been reclaimed from the sea, marshes, or lakes, forming polders (FAO 2010).

The total difference in altitude in the city is about 18 m, with the old town located at 13 m. Around it, there is a large area at 5 m, and it reaches -5 m as one moves away from the centre (Actueel Hoogtebestand 2021).

#### Weather conditions

The Netherlands has a mild climate typical to Northern Europe. Therefore, summers in Amsterdam are generally warm with occasional colder periods, while winters are fairly cold with rain, wind and some snow (lamsterdam 2021b).

However, Amsterdam is surrounded on three sides by large bodies of water, which softens the temperatures, which typically range from 0 to  $6^{\circ}$ C in winter and 14 to  $24^{\circ}$ C in summer.

On the other hand, rain can be expected throughout the entire year, with spring generally being the driest season. The city's average annual precipitation is 838 mm (Koninklijk Nederlands Meteorologisch Instituut 2021).

#### Demographics

With a current total population of 862,987 (2019) in the city centre and 2,507,270 (2020) in the metropolitan area, Amsterdam inhabitants' number is expected to continue growing by a 0.8% rate as in previous years (Macrotrends 2021).

On the other hand, Amsterdam is the 4th densest city in the Netherlands (5,160 inhabitants per square kilometer in 2019 (Statista 2020)), hosting people of 180 different nationalities (lamsterdam 2021c).

#### Government

The City of Amsterdam is divided into seven districts: Amsterdam Centre, West, Oost, Noord, Zuid, Nieuw-West and Zuidoost; each one with its own district committees (City Districts Amsterdam 2021).

The city's systems and policies are created and maintained through dualistic co-operation between the city council and the district committees, and the College of Mayors and Alderpersons. The former is the highest governing body and consists of elected representatives of the people of Amsterdam. Meanwhile, the latter is strongly linked to the voice of the people.

The municipal organisation consists of the seven district organisations (responsible for executive tasks) and four clusters: Economic, Social, Community and Administrative Services. These clusters consist of various departments,



#### UNIVERSITEIT VAN AMSTERDAM





Figure 4.3: Logos of Amsterdam Universities

and they define the policy for a specific field while supporting residents with participation and work (lamsterdam 2021d).

#### Economy

The Dutch economy ranks in the top 20 largest in the world (Worldbank 2021), being the port of Amsterdam the fourth-largest port in Europe (Port of Amsterdam 2021).

Amsterdam is the capital and the principal commercial and financial centre of the Netherlands, where tradition persists alongside innovation (lamsterdam 2021e). Proof of this is the Marineterrain living lab, a co-innovative setting, in which multiple stakeholders (i.e.: universities, institutes, start-ups...) jointly test, develop and create metropolitan solutions (Marineterrain 2021).

Many of the world's largest companies, including leading technology companies (such as Google or Tesla), are based or have established their European headquarters in Amsterdam. The Zuidas (South Axis) district has become the new financial and legal hub of the city (Zuidas 2021). Tourism, retail and fashion are also powerful sectors in the city (lamsterdam 2021f).



Figure 4.4: Property value map

#### **Research & Education**

Amsterdam is also the cultural capital, with universities of great renown and long tradition. The research-oriented universities (for example Universiteit van Amsterdam or Vrije Universiteit) focus on independent thinking, whereas colleges of applied sciences are designed for a specific career (Hogescholen) (lamsterdam 2021g).

Amsterdam's role in international cooperation should also be mentioned, as the city is an EIT hub (being part of the Urban Mobility Accelerator program to support innovative mobility related start-ups) (EIT Urban Mobility 2021) and a member of POLIS (Polisnetwork 2021) and Eurocities (Eurocities 2021).

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## **URBAN MOBILITY ANALYSIS**

With more than 60% of all journeys undertaken via active modes of transportation, Amsterdam is often attributed as being a global leader in modern and sustainable mobility development (Deloitte, 2018).

The current state of urban mobility is dominated by the City of Amsterdam's ambition of becoming Europe's first emission free city by 2025 and its commitment to promote and test smart mobility solutions. This includes a focus on green and sustainable technologies and measures such as the redesign of streets, a changed priority of modes, the promotion of electric vehicles and infrastructure or the promoting of shared mobility solutions.

Historically, cycling has played an important role in Amsterdam's urban mobility, also given the city being dense but flat. While an increased importance of cycling and public transport and a decrease in importance for private cars can be observed, the changes over the last decade are relatively small. This is because compared to many other major European cities the strong shift towards cycling has already happened in the 1970s throughout the Netherlands.

#### Bicycles

Cycling plays a major role in Amsterdam's urban mobility (I amsterdam 2021h). The Netherlands as a whole have a deep-rooted cycling culture that has been developing over many decades by now. Along with the culture the cycling infrastructure has developed over many decades as well. With a total of 767 kilometers of cycling paths and bike lanes, Amsterdam has one of the largest and best developed urban cycling networks in the world. There are 881,000 bicycles in the city and 58% of Amsterdammers use a bicycle on a daily basis.

As part of the City of Amsterdam's mission to reach the zero-emission goal by 2025, cycling plays an ever more important role for success. This has led to a number of measures being tested and/or implemented over recent years. This includes the creation of the so-called "fietsstraats", streets where priority has been given to bicycles over cars. Another development is the increasing number of both cargo bikes as well as electric bikes, that are partially promoted as an alternative to a second car for private households.



Figure 4.5: Modal split 2008

Figure 4.6: Modal Split 2019



While shared bikes without a docking station have been banned from the city in 2017, the Dutch train service provider NS has built up a fleet of thousands of bikes to be rented at stations around the city. Along with the high number of bikes comes the challenge of parking spaces for bicycles which can be seen everywhere on the streets of Amsterdam.

The city has built 25 parking garages for bikes to combat this challenge with more planned. A unique feature of Amsterdam's cycling network is utilizing to use of ferries that are free of charge to connect the southern and northern parts of the city over the river IJ. While they are crucial for many Amsterdammers for their daily mobility, they also still represent a bottleneck increasing travel time for cyclists.

#### Walking

With the dominance of cycling in Amsterdam, walking faces a different challenge than in most other major European cities. While walkability is often limited by car-centric infrastructure, cyclists are the major competitor for pedestrians in Amsterdam. This goes both in terms of infrastructure that focuses more on cyclists than pedestrians, but also simply in terms of the average experience walking in the city and keeping an eye on passing cyclists. To improve walkability there are plans of the city to create an entirely pedestrian focused inner-city center in the old town of Amsterdam.

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#### Private Cars

While being on the decrease over many years, private cars still have their role to play in the mobility mix of Amsterdam. Yet here it is, where the differences between the inner city and its outer districts and suburbs is most clearly seen. While in downtown Amsterdam not many people own a car any longer, people living in the outskirts of the city are still very much dependent on the car for their daily commute.

One important factor in this is the partial lack of public transport in some city districts. At the same time there are measures undertaken by the City of Amsterdam (I amsterdam 2021i). Due to its dense city center up to 90% of Amsterdammers do not have their own parking space, instead relying on public parking. Electric car infrastructure has been promoted by the city over recent years, leading to Amsterdam currently having the densest BEV charging network in the world.



Figure 4.8: Walkability map

#### **Public Transport**

There are four modes of public transport present in Amsterdam: metro, tram, bus and ferry. Currently Amsterdam has five active metro lines with the first two lines built in the 1970s, two more built in the 1990s and the final line opened in 2018. This newest metro line is the first to cross the river IJ, making it one of the few connections of Amsterdam-Noord to the City of Amsterdam south of the river.

In 2018 the Amsterdam metro had an average daily ridership of 247,397 (NRC 2018), culminating to over 90 million journeys done by metro in the whole year. The city's tram lines only run south the river IJ, connecting the city center in all directions with the surrounding city district and some suburbs. Amsterdam's bus lines can broadly be divided into city bus lines running throughout the city and its suburbs, as well as regional bus lines connecting the City of Amsterdam to its surrounding municipalities. A rather unique feature of Amsterdam's public transport systems are the three passenger ferry lines connecting the northern with the southern part of the city across the river IJ. They are free to use and essentially represent an extension of Amsterdam's cycling infrastructure with many cyclists crossing the river via ferry.

While all the public transport options mentioned are present in Amsterdam, especially the metro system is less developed than those of other major European cities in terms of over coverage, connectivity, and number of lines (HERE 2018).



Figure 4.9: Noise map



Figure 4.10: Amsterdam Metro map

# CHALLENGES

#### Challenges of urban planning and mobility

Derived from the basic information on the City of Amsterdam and its urban mobility patterns, sociodemographic, geographic and economic condition presented in the location and urban mobility analysis sections of this chapter this segment describes the main challenges that urban planning and mobility development in Amsterdam faces. These challenges can be divided into four different categories: fundamental mobility challenges, geographic challenges, socio-demographic/socioeconomic challenges and urban development challenges.

#### Fundamental mobility challenges

The most fundamental mobility challenges, which are mainly caused by previous political decisions and the past focus of mobility planning, are visible in the described modal split of Amsterdam. Surprisingly, and against the public and international perception of the City of Amsterdam, as of 2017 most trips (27%) still have been performed by car, with public transport (25%) and walking (19%) only third and fourth place behind the car and biking (26%). Even though there is a positive development for eco-mobility with biking, walking and public transport increasing their share in the modal split and car usage declining (from 32% in 2015), the potential of especially public transport and walking in the city center is by far not yet reached. Therefore, projects presented in the upcoming segments of this chapter, such as the Noord-Zuidlijn, will foster these developments.

#### Geographic challenges

The two main relevant geographic challenges are related to the specific localization of Amsterdam between the North Sea and the Ijmeer. Firstly, there is the IJ, the former bay and now canal that links the North Sea with the Ijmeer, constitutes the waterfront and harbour of Amsterdam, but also functions as a natural barrier in the city separating Amsterdam-Noord and surrounding cities, such as Zaandam (approx. 78,000 inhabitants), Purmerend (approx. 80,000 inhabitants), or Alkmaar (approx. 109,000 inhabitants) from the rest of the City of Amsterdam. Additionally, the origin of Amsterdam as marshlands, which lead to the famous network of canals and drainages, also limits available space due to the high share of water surface of the overall size of the municipality. Therefore, multiple efforts by the City of Amsterdam include the creation of additional usable public space by reduction of traffic and parking spaces, as well as the creation of shared spaces and new areas of development outside the immediate city center.

#### Socio-demographic/socio-economic challenges

Similar to other large and economically attractive European cities and as also shown in the location analysis, Amsterdam experiences a constant increase of population (0.8% increase annually for the metropolitan area with currently around 2.5 million inhabitants), as well as significant gentrification and increasing prices for housing, which lead to push effects towards outer areas of the metropolitan area, as well as the need for additional urban and housing development projects, mainly in areas relatively distant to Amsterdam-Centrum, such as Amsterdam-Noord, Nieuw-West, Amsterdam-Zuid and Zuid-Oost. Here significant influx of new population is expected, accompanied by increasing pressure on mobility infrastructure, a local focus on car usage due to high distances to the center and a lack of awareness, public transport availability and cycling infrastructure. Besides, economic, and social inequalities among different areas of the metropolitan area increase, which, according to local politicians, can lead to unfair possibilities of advocacy for urban development and the emphasis on differences between the central and outlying city districts.

#### Urban development challenges

The general urban development challenges, which obviously also relate strongly to challenges for the mobility development in the Amsterdam metropolitan area, are closely linked to the sociodemographic and socio-economic challenges. The various newly developed areas of the city have traditionally lacked equal connection to public transport and cycling infrastructure, when compared to historic parts of Amsterdam, such as Jordaan or De Pijp. Therefore, large infrastructure projects, such as the 'Sprong over het IJ' and the construction of the 'Noord-Zuidlijn' and other projects have been, are and will be implemented in the last and upcoming years so that a further strengthening of cycling, walking and public transport can be ensured.

All these presented challenges are being tackled by the overarching long-term vision 'Mobility Plan for Amsterdam in 2030' and the small-scale 'Mobility Implementation Plan' and the related specific policy plans for individual modes and topics, which have been developed by the administration of Amsterdam and guide the way for a sustainable and long-term solution to the challenges the metropolitan area is facing (City of Amsterdam Policy nd).





# PROJECTS

Public Mobility & Software Solutions
PCoins
Amsterdam Crowd Management
Vehicle Technologies & Energy
Flexpower
Johan Cruijff Arena Battery Storage
Active Mobility
Bike-friendly Intersections
Utrecht Bike Parking
Urban Planning
The GWL Terrein and De Piip
'Noord-Zuidliin' and 'Sprong over het I, I'
Co-Creation
alluba / Duurthuba

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### PCOINS - A NEW TAKE ON ROAD PRICING

Amsterdam has a high congestion level on its streets, leading to an ongoing discussion on car reduction and road pricing. The PCoin experiment aims at these issues by building a platform that incentivizes a change in behavior and rewards people for not using their cars.

#### **Motivation**

The experiment on PCoins is founded in the need of a reduction in congestion in the City of Amsterdam, as well as in the Netherlands as a whole (Brands et al. 2021). Over recent years as well as in the recent Dutch election, the topic of road pricing has played an important role. The question for the City of Amsterdam is not whether road pricing will be implemented but rather how it will be implemented.

A common approach would be to put a tax, for example in the form of a toll, on driving on certain roads. This would put a price tag on driving on roads in Amsterdam, therefore fulfilling the need of implementing road pricing and promote a reduction of cars on the streets, since not everyone currently using their car would be willing or capable of paying that price.

An alternative approach to dealing with road pricing is proposed in the concept of tradeable mobility permits (Brands et al. 2020), which lay the foundation for the PCoins experiment. Here, car users are rewarded for not using their cars, rather than taxed for using them, in order to change their mobility behavior.

#### Implementation

The experiment was implemented by creating a tradeable parking permit – a PCoin – for parking at the headquarters of ANWB in The Hague. Employees could sign up to the experiment which did run from November 2019 to January 2020. Additionally, an app was created that gave an overview of their PCoins for each user and provided a marketplace for users to buy and sell PCoins. By issuing only 1-2 PCoins per week, with one PCoin being a permit to park for one day, ANWB limited parking to their desired capacity. Employees could then buy more



PCoins if they needed to park more often that week or sell their PCoins if they didn't need them. The price being adjusted by what people were willing to pay.

#### Outcomes

While the sample size of participants in the experiment is too small to make a generalization on behavioral models, there are still some insights given on how participants responded to the incentive given by PCoins. The results suggest that those participants that actively traded with PCoins, did park about 15% less, while others not trading actively seemed not to park less in the incentive period. With their behavior these passive participants did influence the price of PCoins.

#### Discussion

One important criterion for the experiment to be attractive to ANWB employees was to ensure that no one would lose money, which would obviously not be the case if PCoins would be introduced for public parking in the City of Amsterdam. This might explain the relatively large number of passive users, since even without active trading there would be no negative consequences. Promoting active trading and transparency are therefore key for any further implementation.

#### Outlook

Tradable mobility permits have shown their potential for a reduction in parking, yet it remains to be seen in future projects how effective congestion can be reduced in comparison to taxing roads or parking spaces. For now, no further experiments or implementations are planned by ANWB.

#### Applicability to Munich

With Munich facing similar issues on road and parking congestion as Amsterdam, the experiment does give insight that might be applicable to Munich as well. Yet there remains the question whether a tradeable permit like PCoins is more relevant for company parking rather than public parking or usage of different roads.

AIR

A reduction in cars will have a positive effect on air quality, yet the substitute for car travel is not taken into consideration

### SPACE

Space will be increased due to less cars blocking both roads and parking spaces



### **AMSTERDAM CROWD** MANAGEMENT

Amsterdam's crowd management system started 10 years ago with initial pilots and has turned into many permanent setups by now. By making crowd data publicly available through smart dashboards, the City of Amsterdam tries to tackle congestion issues and keep its citizens informed.

#### **Motivation**

The crowd management system in the City of Amsterdam started with initial pilot projects 10 years ago. After initial success the first permanent setups were done in the red-light district of Amsterdam as well as at locations like the area around the Johan Cruyff Arena. By now the system is active in many places around the city, with the Covid-19 pandemic playing a significant role of extending the system to relevant locations for controlling social distancing over the last year.

Starting with the motivation to identify and monitor overcrowded places in the city, the project has by now moved on to additional goals. While it was initially focused on pedestrian traffic, there are also systems in place that monitor cycling lanes and intersections to identify overcrowding. The redesign of spaces identified by the system as usually overcrowded plays another significant role for the city to keep working on their crowd management system, as it enables the identification of such spaces. During the Covid-19 pandemic providing real time data became more relevant to enable the city to close down certain areas due to overcrowding. Collecting data anonymously and in real time has led to the next goal currently targeted by the city, which is to provide its citizens with publicly available dashboards on overcrowding in certain spaces and to make predictions on crowd development. This is supposed to give citizens the chance to make more informed decisions on their movement in the city.

#### Implementation

The implementation of the crowd management system was done step by step, starting with spaces of high congestion like the red-light district or the area around the stadium. Over



the last years many more locations in Amsterdam were added to the system. From the beginning an important aspect for the implementation of the system was privacy. Therefore, different kinds of cameras and sensors were installed, for example true 3D cameras that are not able to recognize faces. And even if, most cameras only provide data, like the number of pedestrians in a street, to the system and no actual video footage. Anonymizing the data at the source and aggregating data are key principles of the crowd management system that prevent identifying the travel behavior of one specific person.

#### Outcomes

The crowd management system of the City of Amsterdam was a continuous success, which is why it is still being developed further. In regard to redesigning space, the system provided data for crowded and overcrowded areas, which is an important basis for policy decision-making. Furthermore, the system enabled the city to act in real time during the Covid-19 pandemic to prevent overcrowding in certain areas of the city.

#### Discussion

While the crowd management system in Amsterdam does have many goals it wants to achieve and many results it has already delivered, there are two main aspects that stand out.

The first is its potential to provide data that makes an argument to redesign spaces. This helps policy makers as well as the city administration to make an argument for change and promote more sustainable and livable designs of streets, parks, or any other areas in the city.

The second is its potential to steer behavior by offering the data in well organized dashboards to its citizens. If the data is provided in an easy to understand and simple to use way, citizens are incentivized to change their movement patterns to avoid crowds which in turn helps to reduce the issue of an overcrowded city.

### ΔIF

Effects on air quality are very only indirect consequences of measures taken as a result of insights gained through crowd management

### **SPACE**

crowded spaces in the city is a key goal of Amsterdam's crowd management system which promotes the redesign of space



Figure 4.13: Crowd Monitoring at Kalverstraat

### Outlook

With continuous growth in Amsterdam, its crowd management system will stay relevant in the future and plans to develop it further are well under way. Moving towards a more predictive model of crowd development will enable the city to steer and incentivize the movement of pedestrians in the city even more than the system already does at this point in time.

#### Applicability to Munich

Amsterdam's crowd management system is more developed than that of Munich, vet many challenges in regard to overcrowding are very similar in both cities. Therefore, there is a lot of potential for the City of Munich to learn from Amsterdam's approach to crowd management and implement some of their solutions as well. Especially the privacy aspects of Amsterdam's crowd management might stand as an example of how to implement such a system in a very privacy wary city such as Munich.



Figure 4.14: Available sensors in the inner city

### **FLEXPOWER - LARGE SCALE SMART CHARGING**

Amsterdam has the highest density of charging stations of all cities worldwide. To minimize the load on the grid during peak hours, the Flexpower project within the Interreg Europe SEEV4-City project set up approximately 900 charging points with time-dependent charging profiles (Bons et al., 2020).

#### Motivation

The primary motivation behind Flexpower was to minimize the load on the electricity grid in Amsterdam, which is in poor condition, especially in the city center. So, the goal was to avoid expensive grid investments with as little influence on the charging time as possible.

At the same time, the overall CO2 emissions should be reduced by matching the charging profile with renewable energy generation during daytimes. All in all, the Flexpower pilot was used to test a large-scale smart charging solution for the existing infrastructure, which reduces the charging power in peak hours and allows faster charging when more capacity is available (Bons et al. 2021).

#### Implementation

Flexpower is based on the architecture of the low voltage distribution system in Amsterdam. No new infrastructure was installed, but 432 (2nd project phase) of the existing charging stations were equipped with time-dependent charging profiles. The "conventional" stations served as reference stations for the charging behavior studies (Bons et al. 2021). According to ElaadNL Innovation Center, the Flexpower stations were placed in Amsterdam South, where many Taxi drivers were living, and in Nieuw West, where many solar energy plants on the rooftops are available.

The flexible profile was configured the following way: During the evening peak hours from 6:00 p.m. to 9:00 p.m., the current is restricted to 8A per phase; otherwise, the current limit is set to 35 A per phase. The timeslot from 6:30 a.m. to 6:00 p.m. depends on the weather: If the probability that the sun will be shining (used parameter: d1zon from 'weerlive' API) is 40% or higher, the current is



### **STAKEHOLDERS**

City of Amsterdam, ElaadNL, Nuon-Vattenfall, Liander, AUAS, Interreg Europe SEEV4-City



### **AFFECTED TRANSPORT**

Electric vehicles (private cars and electric taxis)

#### DURATION

Flexpower 1 (03/17 until 08/18), Flexpower 2 (05/19 until 05/20), Flexpower 3 (started 07/21)

kept at 35A, and at cloudy days, the current is limited to 25A per phase (Bons et al. 2020). The profiles are communicated one day ahead with the charging stations over OCPP (Bons et al. 2021).

#### Outcomes

The data collected in the second project phase showed that 91% of all charging sessions were not affected in terms of charged energy; only 6% of all sessions were negatively affected and 4% positively affected. Moreover, an average reduction of 1.1 kW in peak demand per evening and charging point was realized, which would translate to avoided grid investments of around €47,000.

Nevertheless, the CO2 emission reduction from applying the Flexpower charging profile was minimal (only 0.07 % reduction total). In addition, the flexible profile created a rebound peak, which was even higher than the original demand peak. However, as the peak occurs when household demand has already decreased, the total load on the grid is more evenly distributed (Bons et al. 2020).

#### Discussion

Flexpower has shown that even a simple static time-dependent charging profile can significantly reduce the load on the grid. However, instead of the static profile, a dynamic profile adjusted in real-time according to local demand and supply would be beneficial, as this would also allow a better adaptation to the power peaks of local photovoltaic systems. Technical implementation is realizable with OCPP, which has real-time capability and is already in use. Besides, applying the Flexpower smart charging profile caused several challenges concerning software and hardware: This included a manual upgrade of the grid connection, replacing fuses, and upgrading the firmware (Bons et al., 2020).

Furthermore, the Covid 19 pandemic impacted the second phase of the project, which had to be terminated early because no one used the charging infrastructure. As reported by Elaad, more than one year of data collection is consequently missing.



![](_page_71_Picture_25.jpeg)

Figure 4.15: Flexpower Charging Station in Amsterdam

#### Outlook

According to Elaad, Flexpower started in its third phase in July 2021. The main objective is now working with firm and non-firm capacities: In the new model, a minimum capacity during the whole day is guaranteed for the grid connection points, and if there is a surplus of energy, it can be used for faster charging. This real-time adjustment of the charging profile depending on actual occupancy and demand levels also allows a better fit with renewable energy generation (Bons et al. 2021).

### Applicability to Munich

With the increasing number of EVs, Munich will also reach a point where the grid can get overloaded during peak hours. In this respect, it makes sense to introduce a time-dependent charging profile early and make sure that charging stations are prepared for it by including firmware that enables applying, e.g., 0CPP (Bons et al. 2020).
# **JOHAN CRUIJFF ARENA BATTERY STORAGE**

The Johan Cruijff ArenA is already known as one of the most sustainable stadiums in the world. Within the Interreg-funded SEEV4-City project, the JC ArenA is one of six operational pilots demonstrating the combination of solar power, large-scale battery storage using second-life EV batteries, and V2G technology (van den Hoed et al. 2019).

# **Motivation**

Besides the general objectives of all SEEV4-City pilots (reduce the emission of CO2, increase energy autonomy, avoid grid investments), the JC ArenA has an interest in reducing its carbon footprint concerning the Clean Air Action Plan of the City of Amsterdam, including the inner city to be emission-free by 2030 for all forms of transport. These goals should be implemented with a battery energy storage system (BESS) connected to the PV system on the rooftop. With the integration of a V2G-charging unit allowing for bidirectional charging, the arena should be a shining example for combining different energy services in parallel. Constructing the BESS by second-life EV batteries should additionally show that old EV batteries are well-usable for large-scale battery storage purposes (Warmerdam et al. 2020).

## Implementation

The static battery was delivered by Nissan, comprising 148 Nissan Leaf battery packs (40% second-life). The system has a capacity of 2.8 MWh and a power of 3 MW and allows grid services like, e.g., optimized PV integration, FCR, and Peak Shaving. The PV system on the roof has a maximum output of 1.128 MW. It was connected to two more transformers in order to increase the energy autonomy of the system.

Furthermore, 14 AC chargers of 22 kW each were installed together with a smart energy management system to save installation and cabling costs. Finally, one V2G unit with 10 kW power was integrated into the system allowing electric vehicles to power events or to be charged with energy out of the BESS. All energy services by the BESS, the EV chargers, and the V2G-unit are managed by The Mobility House (Warmerdam et al. 2020).



# $\overline{}$ visitors and employees)

#### Outcomes

The three SEEV4-city project main objectives have been reached: 2012 tons of CO2 were saved 2019 because of the BESS, the energy autonomy was increased due to a better spreading of the energy generated by the PV over the available transistors, and the BESS caused a grid investment deferral by a peak demand reduction of 10% (Warmerdam et al. 2020).

**STAKEHOLDERS** 

DURATION

Johan Cruijff ArenA, EATON,

**AFFECTED TRANSPORT** 

Installation 2018/2019

Nissan, The Mobility House, BAM

Techniek, Liander, TenneT, AUAS

Electric vehicles (private cars of

### Discussion

As there are very few plug-and-play systems for the combination of PV, battery storage, and bidirectional charging currently available on the market, pilots like JC Energy ArenA can drive innovations forward in this area (Van den Hoed et al. 2019). In addition, the successful combination of multiple energy services and technologies at the JC ArenÁ demonstrates that locations do not have to commit to one specific technology but can also implement multiple technologies simultaneously. Besides, the construction of the BESS using second-life batteries can be a development model for other stadiums worldwide (Warmerdam et al. 2020).

However, the BESS was planned to be constructed only of second-life batteries, but due to the low availability when the project started, only 40% of the batteries are secondlife. This issue may be obsolete in the future when more second-life EV batteries are available. Additionally, balancing the secondlife batteries with the new batteries was a significant challenge for The Mobility House because the older batteries acted differently than new ones (Warmerdam et al. 2020).

Another problem, according to the Hogeschool van Amsterdam, was the limited hardware available at the project launch: V2G stations and DC chargers that could have been directly connected to the BESS were very costly. For this reason, only one V2G station was implemented, and cheaper AC chargers have been used instead of the DC chargers, which required an additional AC-DC conversion. Consequently, the connection of the charging stations to the BESS is not optimal, and there is still much potential in energy utilization if, e.g., more V2G stations were installed.





Figure 4.16: The BESS in the basement of the JC ArenA

# Outlook

There are plans to install hundreds of charging stations in the ArenA; several business cases are also proposed to be tested, e.g., with reduced parking fees for people who use the V2G units (Warmerdam et al. 2020). According to Hogeschool van Amsterdam, installing a DĆ grid for the complete arena to better integrate DC chargers into the BESS is planned.

## Applicability to Munich

A BESS like the one in JC Arena might be interesting for, e.g., the Allianz-Arena as the advantages (peak shaving, CO2 reduction, ...) are also profitable for Munich, and just as in Amsterdam, a powerful PV system is available nearby. Although legislation might be slightly different in Germany, it would be worthwhile to do calculations for the Allianz-Arena or other possible implementation places whether it is economically and ecologically viable to install a large-scale BESS.

# **BIKE-FRIENDLY INTERSECTIONS**

The bicycle has become the most used means of transport in the City of Amsterdam (lamsterdam 2021). However, in order not to be a victim of its own success, the city keeps working to avoid congestion so that the bicycle continues to maintain its attractiveness and leadership.

### Motivation

The rapid growth in cycling in some Amsterdam neighbourhoods is putting pressure on the cycling network, which is reaching its maximum capacity at the busiest intersections (Bicycle Dutch 2018). Around 2,000 cyclists go through one of these intersections in the morning peak and approximately 30,000 throughout the whole day (Amsterdam Bike City 2021).

However, public space is limited so Amsterdam is testing new ways to use the existing space more efficiently (City of Amsterdam 2021a). They want that cycling remains convenient and attractive by providing more space and shorter waiting times for cyclists, even if that means deviating from standard design manuals (Amsterdam Metropolitan Court 2020). It finally resulted in award winning solutions.

Among the strategies being used are the removal of protective barriers, space redistribution, altering light phases, reducing vehicular speed limits and designating entire corridors as "bicycle streets". One of their main goals is to improve traffic flow, comfort and road safety at intersections. These pilots are part of a larger mobility strategy across the city to make more room for cyclists and pedestrians, limiting access and space for private vehicles (City of Amsterdam 2021b).

#### Implementation

The municipality uses an innovative approach in which the intersections are adapted to the cycling natural behaviour. This also promotes compliance with traffic regulations. Due to space and financial constraints, these capacity improvements are meant to be achieved with minimal interventions while consulting the citizens.



**STAKEHOLDERS** MLW, UvA, Urban Cycling institute, Engineering Consultancies and Copenhagenize

**AFFECTED TRANSPORT** Bicycle, with space and time redistribution affecting pedestrians and road modes

# DURATION 2017-2022

In the initial situation, cyclists' behaviour is analysed at intersections to subsequently develop appropriate measures for the proposed design and test them through experiments. In addition to these measures being extensively monitored and evaluated in practice, a large amount of research is done on cycling behaviour, perceptions and experience.

The national guidelines of the CROW, the municipal Guideline Central Traffic Commission, or the usual road layout are also questioned in order to meet the new needs.

### French Fries/Chips Cone

The French Fries Cone consists of placing diagonally the directions' dividing line for cyclists at a crossing, creating two cone shapes. By placing the centre line diagonally, the waiting space side by side before the stop line at the light can increase significantly. As could be observed, cyclists tend to position themselves to the side rather than form a aueue.

Since the lane gradually narrows as one approaches the other side of the road, this involves the funnelling of cyclists on two-way paths due to the differences in speed. This has a positive influence on the time it takes for the crossing to be cleared.

As a result, more cyclists can start moving at the same time and more can actually cross the road in the same green time. Or seen in another way, the same amount can cross in less time, reducing the red time for other modes and increasing the overall efficiency of the intersection.

#### Space-saving Banana

Another solution to increase the space's efficiency is the space saving Banana. The traditional protecting traffic islands are large, rendering valuable space unusable. The form can be then changed from a petal-shape to a banana-shape, recovering a lot of that space. The new form's minimal size is dictated by the necessary turning radius combined with the width of the kerb stones, while leaving enough space for the traffic signal and drainage.

Defending the attractiveness of bicycles, prevents relative emissions (Sensible Transport, 2018)



Figure 4.17: Alexanderplein junction

#### Traffic lights Off

This type of experiment was performed in intersections described as chaotic where traffic rules were not respected. As it later turned out, red times were the moment to zone out for many road users, after which everyone would speed up, with little to no interaction between them (Glaser 2017).

The experiment involved the shutdown of all traffic lights for all transport modes in all directions. Therefore, the operation was supervised by Amsterdam officials, engineers, and civil servants (police and public transit authority), in order to make sure that road safety was by any means compromised.

As a result, users started slowing down as they approached the intersection and paid more attention. This human centred-design forces road users to engage with their surroundings and negotiate in motion. An increase in interactions can also lead to social cohesion and even social capital (Glaser 2017).

"This pilot showed that less regulation can lead to responsible and alert road users," said Litjens, vice mayor for traffic.

A technical study followed, evaluating safety, conflict and traffic flow. It showed that delay was reduced and safety unaffected, while surveys declared a general satisfaction with the change, avoiding forced stops.

#### Outcomes

Despite the promising primary results and useful insights into cycling behaviour, the Amsterdam Court of Auditors stated that monitoring was not sufficiently systematic. In line with this, meaningful indicators were lacking and not all results were recorded, making the assessment of improvements in effectivity and efficiency more difficult.

On the other hand, the initial total budget was € 1.6 million and 150,000 € per intersection. However, the costs per intersection were finally twice as high as budgeted. Time also seemed to be underestimated, since by 2020 only 2 out of the planned 10 intersections were studied.

# **Deep Dive**

Due to the Covid-19 outbreak, many governments forbid unnecessary mobility circulation (Lozzi, Marcucci, Gatta, Panteia 2020).

That was also the case of Amsterdam, where only essential workers were riding their bikes.

With the reopening, the bike keeps playing a decisive role as a substitute for PT.

For example, the municipality provided 1,600 bikes for students to ensure safe travel and to discourage the use of PT (European Parliament 2020).



Figure 4.18: French Fries/Chips Cone design



Figure 4.20: Safe intersection near Amsterdam Amstel Station

# **UTRECHT BIKE PARKING**

The world's largest bicycle parking was opened in Utrecht the 19th August 2019. With a total of 12,500 parking places, it is the only manned and monitored bicycle parking where indoor cycling is permitted (City of Utrecht 2021).

## Motivation

The popularity of the bike in a city can be challenged by the insufficient amount of cycle parking facilities, reducing its attractiveness for potential new bicycle users. Moreover, illegal parking in places with space scarcity, threatens the well-functioning of public space.

In its aim to become a liveable city and promote the modal shift towards sustainable mobility even further (Utrechtregion 2021), the City of Utrecht decided to improve the accessibility to its railway station for cyclists. The new bike parking is an integral part of the renewed railway station.

The main objective is to provide cyclists with an attractive, safe and efficiently used bicycle parking. Users can cycle on the way to the parking spot with easy access to the platforms, station halls and buses, reducing their travel times. The passage from the parking to the city centre and to the central station also serves this purpose.

#### Implementation

The parking's building time lasted almost 5 years, during which time the station remained fully operational. The construction was made in stages, first opening in August 2017 with 6,000 places, increasing to 7,500 in October and being finally completed in 2019 offering 12,500 places (Bicycle Dutch 2019).

On the other hand, the total cost of the 350 metres long parking lot amounted to over 30 million euros or more than €2,400 per parking space.





# DURATION 2015-2020

At the 2 entrances, a digital system gives information and guides cyclists to the free parking places (floor and racket) inside the parking. This system also helps authorities enforce the parking policy and regulations.

**STAKEHOLDERS** 

(Dutch Rail)

Municipality of Utrecht, ProRail,

Ministry of transport and NS

#### Connections

Inside of the installation, parking is offered at 3 different levels reached by cyclable ramps:

- First floor: Reserved for bicycles that are parked for the day. From there, one flight of stairs leads to the square on top of the garage.
- Ground floor: Meant for subscriptions' holders (75€/year). The strategical location of the parking provides cyclists with a short cut through the ground floor for free.
- Basement: Also for parking for the day. In this level, there is a tunnel with direct access to all train platforms.

### Tarif

During the first 24 hours, parking is free. Cyclists must only check in and out with their public transport chip card, scanning the QR code of the parking place used. In case of not owning an OV chip card, a loan card from the administrator can be used.

From that, the daily tariff increases up to 1,25 €. After 28 days, bicycles are removed by wardens, who also monitor correct parking.

#### Special bikes

Bikes with baskets or children's seats have their own area. However, bicycles that are widely different from normal bicycles, such as carrier bicycles, can be parked in another parking lot: the Sijpesteijn Bicycle Parking.

A number of places have plugs for charging ebikes.

# ΔIF By promoting the significantly reduced



#### Services

On the other hand, 1.000 public transport bicycles, called OV-bicycles, are also provided. This scheme is open to both Dutch residents and non-residents with a Dutch bank account who have access to a Dutch address. This prevents tourists from enjoying the same benefits.

Other bike sharing operators like Donkey Republic also have a reserved place.

The bicycle installation also counts with a bicycle and service point for repairs, maintenance, parts and accessories.

#### Outcomes

After two years, the occupancy rate on Monday, Wednesdays and Fridays were calculated to be between 80 and 90%. And on Tuesdays and Thursdays the garage was often full. However, users rate it with an 8 out of 10.

Besides, the first two years of use have shown that people choose their floor based on their destination. Those aiming to catch a train are more likely to park in the -1 level, meanwhile those working in the vicinity visiting clients as well as those heading to the mall, prefer the upper level.

#### Discussion

The Utrecht parking garage is a good example of how a parking garage can be well integrated into a larger system of a central station and at the same time be a piece that shapes the territory around it and provides access. Its good design stratifies the different uses and accesses so that its space is used efficiently by the different flows avoiding crowds.

Although the money for its construction may seem apparently high, it should be taken into account that its  $1,200 \notin$  per parking space is only a fraction of the cost per parking space of a common parking lot for private vehicles (around  $20,000 \notin$  for abovegroundparking and  $30,000 \notin$ for undergroundparking)(Shoup 2014).

Despite the great efforts made to provide more parking, other measures should be taken to avoid infringing on public space. The number of bicycles in 2019 in the Netherlands was estimated at 22.9 million (Wagner 2021) against a population of 17.2 million (CBS 2021), highlighting the fact that residents own at least one bicycle. Measures that promote bike sharing or the use of national bicycles should be encouraged from a resource efficiency point of view.

### Outlook

The parking lot is expected to be insufficient for the demand by 2025, and the city is already working on new solutions. In this regard, in 2021 there was already an unexpected growth of the number of rail passengers, from 1,9 to 4,6%. On the other hand, Amsterdam, which already has 9 parking lots (City of Amsterdam 2021c), is renovating the entrance to its main station with an integrated parking lot that will accommodate up to 7,000 bicycles (City of Amsterdam 2021d).

## Applicability to Munich

Just like in most of Dutch cities, bicycle theft in Munich is a big problem (6.050 in 2020) (Rudnicka 2021). Although the popularity of cycling in Munich is mainly season dependent (Kruse, Witzenberger, Zajonz 2018), the renovation of the station, due for completion in 2026, will only increase the number from 692 (City of Munich 2021a) to 3,000 bicycle parking spaces (City of Munich 2021b). Apparently, and according to a survey, this number is sufficient for the current demand as bicycles accumulate illegally at the station entrance, hindering pedestrian access. However, it could be insufficient for the horizon year, where a possible increase in demand is unknown, making the bike and ride scheme unattractive and hindering modal shift.



Figure 4.22: Guiding system inside the garage



Figure 4.23: Smakkelaarsveld Entrance at ground level



Figure 4.24: Inside the garage

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# THE GWL TERREIN AND DE PIJP

The GWL-Terrein (GWL=Gemeentewaterleidingen, municipal water company) in Amsterdam-West and De Pijp in Amsterdam-Żuid, while historically different, share one attribute: they are ideal-typical examples of car-reduced and bicycle-centered neighborhoods. The GWL is an example of car-reduced design, while historic De Pijp experienced transformation.

## **Motivation**

Car usage in Amsterdam increased since the 1960s, deaths in accidents peaked in 1970-1972 (110 annually). This sparked initiatives for safer roads like "Stop de Kindermoord", founded in 1972 in the 19th century working-class neighborhood De Pijp (Amsterdam-Zuid). Steady transformation away from car ownership, especially in De Pijp followed (Feddes & de Lange 2019).

The GWL-Terrein was created on the property of the Municipal Water Company in Amsterdam-West from 1993 to 1998 as the first car-reduced neighborhood after local citizens' pressure. The planning focus was on participation, cooperative ownership, a low parking lot ratio (0.215), sustainability, mixed zoning, rented and private apartments (GWL-Terrein n.d.; SDG21 2019).

### Implementation

The transition process of De Pijp was induced by transferring multiple streets to 'Woonerfs' (traffic calmed areas). Based on civic participation, various infrastructure changes evolved: a connection to public transport, large bike parking facilities (e.g. 700 spaces at Ceinturbaan Metro), the Albert Cuyp Garage, a parking garage under the car Ruysdaelkadegracht for 600 cars and emobility hubs.

Along with the reduction of car ownership rates, existing car parking spaces were transformed into urban gardens, public spaces, gastronomy, and bike parking (Feddes & de Lange 2019; VA 2018; ZJA 2019). Transformative processes were enhanced during the Covid-19 pandemic, when commuting decreased significantly.



#### **STAKEHOLDERS** Local citizens and businesses, city district, housing corporations and planners



#### **AFFECTED TRANSPORT** Private cars versus shared

vehicles, bikes, walking and public transport

#### DURATION

Transformation in De Pijp since 1972, GWL planning since 1993

In the GWL Terrein a limited number of parking spaces for inhabitants were planned from the beginning, only along the east side of the residential area in the Waterkeringweg and Waterpoortweg. Overall, there are 129 parking lots available for 600 dwellings on the six hectare compound, yet every building disposes sufficient bike parking in cellars, shared vehicles are available on the Terrein and the connection to public transport is ensured via one tram and multiple bus stations (GWL Terrein n.d.; SDG21 2019).

#### Outcomes

As a result, both parts of the city belong to the most bike-oriented parts of Amsterdam, leading to 46.6% - 54.4% of all trips performed by bike in the GWL-Terrein and its surrounding area, as well as in the southern parts of De Pijp and 38.0% - 46.6% in the northern parts (Harms & Neallo-Deakin 2019).

Despite the increased modal share of biking, De Pijp experienced gentrification and a reduction of inhabitants to a fourth (around 33,000) from the 1970s, a reduction of car ownership, even leading to a large share of unused parking spaces in the Albert Cuyp Garage and emerging public spaces (Amsterdam.info n.d.; Mobycon 2021).

In the GWL Terrein car ownership remains at low levels, even though inhabitants rent additional parking spaces outside the compound and the spirit towards mobility and sustainability has changed due to constant relocations. Both neighborhoods exhibit similar socio-demographic characteristics, mainly well-educated young adults, or families (Harms & Neallo-Deakin 2019).

### Discussion

From a mobility, social and urban planning perspective the GWL Terrein and De Pijp exemplify proven approaches to car-reduction in existing and new neighborhoods if alternatives are fostered and civic participation is enabled. Yet there are limitations to both approaches, for example the change in attitude in the GWL Terrein and the cost of parking spaces in De Pijp.



in both neighborhoods

due to a reduced

amount of exhaust

gases

**SPACE** The inhabitants of the car-reduced GWL Terrein and De Pijp profited mainly by the surplus of public space for various quality-oflife enhancing activities



Figure 4.25: Amsterdam De Pijp street redesign

# Outlook

Both examples are used as role-models for the development of new city districts in Amsterdam, such as in Amsterdam-Noord, or for the transformation of existing historic neighborhoods, such as Jordaan (Amsterdam-Centrum).

## Applicability to Munich

Due to the characteristics of the GWL Terrein and De Pijp in Amsterdam as car-reduced neighborhoods, the two can be adapted for transformation or development processes in Munich, though the concrete measures must be adapted to the specific context.

# **Fun Facts**

For a dry throat: The GWL Terrein was built on the site of the Municipal Water Company and the Heineken brewery originates from De Piip.

The time benefit of car-reduced neighborhoods is difficult to indicate, but probable to exist due to significantly decreased traffic congestion



Figure 4.26: GWL Terrein Amsterdam

# **'NOORD-ZUIDLIJN' AND 'SPRONG OVER HET IJ'**

To connect Amsterdam-Noord, separated by het IJ (former bay, now inland canal), with the rest of the city and guarantee a better passage from the very South to the very North of Amsterdam two infrastructure projects are being implemented: the 'Sprong over het IJ' and the 'Noord-Zuidlijn'.

## **Motivation**

The two infrastructure projects 'Sprong over het IJ' and the 'Noord-Żuidlijn' are rooted in geographical, infrastructural, and urban characteristics of Amsterdam. Geographically, the IJ is the former bay and now partly canal connecting the limeer in the East with the North Sea to the West of Amsterdam. It constitutes the waterfront of Amsterdam and separates Amsterdam-Noord from the rest of the city. This 'border' will be traversed via both projects. Infrastructure connecting northern with southern parts of Amsterdam historically has been lacking. Public transport relied on buses in Amsterdam-Noord, metros and trams provided east-west connections south of the IJ, supported by bus lines. The outer highway ring (5km radius around Amsterdam-Centraal), one tunnel and one bridge constitute connections for cars. Pedestrians and cyclists depend on free-of-charge ferries (time penalty = 5 minutes). These limitations have been seen as a constraint for mobility in Amsterdam by all relevant actors in the Amsterdam administration and communal politics. The future city development of Amsterdam enhances the need for a north-south connection, since Zuidas (Amsterdam-Zuid) and Amsterdam-Noord are, according to local administration, centers of future city development with a combined total of more than 100,000 inhabitants in the next 30 years (Zuidas n.d.).

### Implementation

The 'Noord-Zuidlijn' (decision in 1996, construction 2003-2018) is 10km long with a bidirectional six-minute interval with 8 stops from Buikslotermeerplein (Amsterdam-Noord) to Amsterdam-Zuid via De Pijp and Amsterdam-Centraal. The construction was controversial, delays and construction obstacles occurred



**STAKEHOLDERS** City of Amsterdam, Rijkswaterstaat, GVB, federal government

#### **AFFECTED TRANSPORT**

Public transportation via metro and ferry, biking, walking, <u>ل</u> motorized vehicles

#### DURATION



Noord-Zuidlijn: opened 2018 Sprong over het lJ: preliminary decision 2021

and the final cost exceeded 3 billion € (Brands, Dixit, van Oort 2020; Arts, Howitt, Miller et al. 2020). The 'Sprong over het IJ' has been debated by Amsterdam administration and local politics since 2015 and was decided in 2021, but the exact plan is not yet developed. The project might include bike and pedestrian bridges at Amsterdam-Centraal, a tunnel, electric ferries, moving the ferry landings and the redesign of the north-side of Amsterdam-Centraal where large bike-parking (ca. 6000 bikes) and shared spaces will be implemented. The next steps are planned for the first quarter of 2022 (Amsterdam n.d.).

### Outcomes

An accompanying impact analysis of the 'Noord-Zuidlijn' in 2018 determined that initial effects focused on a 4% increase in working day metro usage, a shift to metro, 21% of travelers with reduced travel times and 13% of travelers with increased travel times (Brands, Dixit, van Oort 2020). Additionally, there is a perception that the willingness to see the benefits of the new metro line is steadily increasing, especially with the complications of the planning and construction process becoming more distant. The impact of the 'Noord-Zuidlijn' might also benefit from increasing usage after the end of the Covid-19 pandemic. The hoped-for outcome of the 'Sprong over het IJ' includes reduced travel times, mainly for cyclists and pedestrians, a more pleasant waterfront at Amsterdam-Centraal, more bike parking and environmental benefits for het IJ and whole Amsterdam.

### Discussion

Though the complications of the 'Noord-Zuidlijn', unexpected additional costs and limited immediate benefits led to poor public support for the project, the long-term benefits of the project for public transport and urban development, the chances of a post-Covid future and the planned role of the new line as backbone of the metro system make the project a likely long-term success. For the 'Sprong over het IJ' expectations, at least in local politics, are similar, even though past experiences with the 'Noord-Zuidlijn' might make active communication on and advocacy for the planned project mandatory.



# engine powered transport and



Figure 4.27: Route of the Noord-Zuidlijn

## Outlook

The city council and administration is progressing plans on prolonging the 'Noord-Zuidlijn' from Amsterdam-Zuid to Schiphol airport, a project that will be funded by the Dutch National Growth Fund and executed in the upcoming decade. Together with the potential of the already existing line, the new metro will be central for mobility in Amsterdam. This might also be the case for the 'Sprong over het IJ'.

## Applicability to Munich

Both projects are only indirectly applicable to Munich due to specific characteristics of the IJ, which is a larger natural barrier than the lsar in Munich. Yet both cases show that ambitious and brave planning and implementation of large infrastructure projects including the population despite criticism can help transform mobility patterns on a grand scale. Additionally, the detailed scientific monitoring and impact evaluation of the two projects can function as a role model for Munich.

# **EHUBS / BUURTHUBS**

eHubs are spaces in neighborhoods of Amsterdam that offer different types of shared electric mobility, such as electric bikes or cars, to its citizens. There are two types of eHubs: commercially offered eHubs and so-called BuurtHubs, created and run by the citizens themselves.

### Motivation

The eHubs are a European project funded by Interreg North-West Europe (nd). With the City of Amsterdam as leading partner, cities from 6 European countries have set themselves the task to implement on-street hubs that provide a diverse offer of shared and electric mobility services to their citizens. The goal of these eHubs is to give citizens an alternative to private car ownership, leading to a reduction in cars on the streets of the city and an overall cleaner and more livable city.

The City of Amsterdam identified two different approaches to the creation of eHubs. First, there are commercial eHubs which are set up with a private company as a partner that runs the eHub. This company is the one deciding on which vehicles to offer and with which shared mobility providers to work with. The second approach is that of the BuurtHubs, which are eHubs developed and run by people in their own neighborhood as well as in close cooperation with the City of Amsterdam (Amsterdam Buurthub nd1). The idea is to give citizens a say in what modes of transportation they want and include them in the development process.

### Implementation

Different mobility service providers in the area of shared electric mobility have been won for a cooperation with the BuurtHubs, giving citizens a selection of choice when participating in the creation of their neighborhood's BuurtHub. The City of Amsterdam informs their citizens of a BuurtHub being planned in their area and invites them to participate and vote on the exact setup of the BuurtHub. Therefore, BuurtHub or eHubs in general can look very different in terms of size and the offer available depending on where they are implemented and what the citizens decideded on.



While eHubs at locations such as train or metro stations are mostly planned with a top-down approach by the city itself to create mobility options for travelers, the BuurtHubs in the neighborhoods follow the top-down approach by letting citizens participate. Leaders are identified in the neighborhood that are willing to take the project further by creating events that invite others to participate. One example of this was organizing a small street festival with different electric vehicles present so that everyone can test them. The City of Amsterdam supports these events, as well as the BuurtHubs themselves, with marketing, organizational support, and funding.

This is what makes the implementation of eHubs in Amsterdam a special and interesting project to study. Over the coming years several eHubs will be implemented in Amsterdam, yet only a few are already implemented as of this moment.

#### Outcomes

Being a newly implemented project, the first outcome of the project can mostly be seen in the question of marketing. Information and

transparency to the citizens are key in establishing an eHub and convincing people to try it out. People need to be aware of the option and the entry barrier needs to be low.

### Discussion

Currently being a young project, it is not very clear to say whether eHubs will play an important role using space in cities in a different way while also providing different modes of transportation. Similarly, it cannot be concluded yet whether a top-down approach, a bottom-up approach or a mix of both will be the way to go forward. Yet the project in Amsterdam has given interesting insight on how such eHubs might be implemented and introduced the notion that citizen participation and co-creation might play an important role in convincing people to not own their own cars anymore. This last point is in its current form unique to Amsterdam and might be an interesting project for other cities to look at.

# 

Promoting electric vehicles has the potential to increase air quality by reducing the amount of combustion engine vehicles

# SPAC

is redesigning streets by using previous car parking spots to offer several types of shared electric mobility



Figure 4.28: Buurthub in Amsterdam De Pijp

# Outlook

The eHubs project is designed as a pilot project in a limited number of cities to test the concept and set an example of how eHubs might play a relevant role in a more sustainable redesign of cities in Europe. The first steps in Amsterdam show the potential of eHubs being part of the City of the future and therefore more testing and implementation can be assumed.

## Applicability to Munich

With private car reduction and a redesign of space being important topics of discussion in Munich, eHubs have the potential to play a role there as well. While it is difficult to simply copy and paste a blueprint of a solution to a different city, the insights from Amsterdam can very well help Munich in deciding on the approach to be followed when creating, testing, and implementing eHubs.



Figure 4.29: First showcase of BuurtHub in Amsterdam

# CONCLUSION

To conclude the presented research and overview on the present and future of urban mobility in Amsterdam, the following section of the research report, after a short summary on the described projects in each category, will demonstrate the overall projected benefit for air, space, and time in the city. Thereupon, an overall assessment of the degree of innovation and progress in the field of urban mobility in Amsterdam and the potential of the described projects and measures to solve the initially evaluated challenges for urban planning and mobility in the metropolitan area will be given.

The two projects that have been evaluated in this category, the PCoins project and the Crowd Management System in Amsterdam, even though they both are not classic examples of public mobility or Mobility as a Service, provide innovative approaches to mobility as they must be viewed as unique software implementations that both help to use available public space more efficiently by steering people behaviors indirectly, without stringent regulation necessary. Additionally, both measures have shown their theoretical realizability in real-world implementations. The PCoins project, unlike the implemented Crowd Management, also has the potential to help creating a better air guality and urban environment by reducing car usage in the long run.

The Flexpower and the overall smart charging infrastructure implemented on a large scale in Amsterdam, as well as the battery re-usage concept at the Johann-Cruyff-Arena show the way into a more sustainable, circular, and smart electric vehicle technology future and thereby shine a clear light on how measures with a significant positive effect on all three categories, air, space, and time, can be developed. Besides, these two projects have a very high relevance for the context of every urban center, such as Munich.

Consistent with the public and international reputation of Amsterdam as a major cycling hub, the selected measures and projects for active mobility, mainly adaption of a cycling-friendly infrastructure, parking facilities, innovative traffic management, cycling focused traffic planning and related street experiments, have significant potential, mainly through a modal shift away from car usage and towards more cycling, to generate more available public space, better air quality and more fluid trips with efficient travel times. Therefore, Amsterdam really can function as a role model for all forms of active mobility.

Like the focus on active mobility in Amsterdam, also the measures for car-reduced neighborhoods, either newly developed or transformed, can function as a proven role model for other cities due to the inherent high potential for generating additional available public space via car reduction. On the contrary, the 'Sprong over het IJ' solves a specific geographic problem in Amsterdam, even though the principal nature of such large-scale infrastructure projects can give inspiration for urban development in other metropolitan areas.

The chosen project on co-creation, the Buurthub concept, shows that car-reduction and the abovementioned transformation of existing and new neighborhoods can be performed as a bottom-up participatory and inclusive project, which allows to consider the needs of citizens in terms of mobility demand, as well as desire for more livable cities.

Due to the ubiquitous focus on a modal shift away from car-usage and towards cycling and public transport, most measures and projects implemented in Amsterdam for a more livable and sustainable future of mobility the category air profits gravely from the transitions performed in Amsterdam.

As described in the challenges section of the Amsterdam chapter of this report, the prevalent lack of public space in Amsterdam is a constant challenge for urban planning. Therefore, most described measures and projects focus heavily on the creation of additional usable public space, mainly the reduction of car usage and car ownership rates. Therefore, the space category can be seen as the most progressive of all in the Amsterdam case. Since the focus of mobility planning in Amsterdam is not primarily on optimizing travel times, even though this is always considered, for example in public transport related projects or the 'Sprong over Het IJ' and the active mobility innovations, here the effects must be considered relatively marginal, yet not inexistent.

As seen in the evaluation above, the degree of innovation and progress in urban mobility in Amsterdam is quite significant, especially in the fields of active mobility, car-reduction and public space generation and a more sustainable vehicle technology future. Here the city must be regarded as a valid role-model for other urban centers.

When lapping the derived challenges in Amsterdam with the presented measures and projects a problem-solving attitude becomes visible, due to practically all projects tackling one of the four categories of challenges. Especially the needed modal shift away from car usage, the bridging of natural borders, the gain of available space, and a more inclusive urban development and more accessibility to public transport help solving the pressing issues of the Amsterdam metropolitan area.

# **CROSS-CITY ANALYSIS**

According to the Wuppertal Institute, Copenhagen, Amsterdam, and Oslo respectively occupy the top three positions in terms of sustainable mobility (Wuppertal Institute 2018). However, these three cities have achieved these promising results through different strategies, with differing intrinsic characteristics, and while facing different challenges.

#### Demographics

In terms of population sizes, Amsterdam, Copenhagen, and Oslo have sizes of the same order of magnitude, while Munich is twice as large.

The population growth rate in Oslo is notably higher than in Amsterdam and Copenhagen. However, the population density is less than half that of the other cities, leaving room for the city to maneuver and accommodate this demand.

Especially Munich will face a big challenge due to its high growth rate with a density already higher than that of Amsterdam and Copenhagen (City of Munich 2021). High population densities favor public transport (Kinder Institute 2018), which must be managed in advance to avoid congestion in the system, like the case of Munich before the pandemic (Effern, Hilberth, Hutter & Krass 2018).

2021	Munich	Amsterdam	Copenhagen	Oslo
Population (K inhabitants)	1,562	873	799	693
City's size (km²)	311	220	180	454
Population density (inhabitants/km²)	5,000	3,980	4,400	1,626
GDP per capita (K USD)	84	73	62	66
Growth rate (%)	1.13	0.71	0.98	1.48

Table 5.1: City demographics

#### Modal share

Overall, all cities have a high rate of private car use. However, the cycling city titles of Amsterdam and Copenhagen are due to the different modal split in their centers, where cycling is the most attractive mode. New urban developments in Amsterdam, due to their distance to the center, urban structure, and lack of amenities, are more car dependent. Also, Amsterdam achieves low car use in the city center (City of Amsterdam 2021) due to its parking policy among other measures.

In the case of Oslo and Munich, public transport becomes the predominant mode in the city center. The cycling share in Oslo remains relatively low in the city center, which can be attributed to high elevation changes throughout the city and a preference for e-scooters. Munich shows promising results regarding cycling share, however, bike use in the city remains seasonal (Kruse, Witzenberger & Zajonz 2021). Moreover, recent years show a decline in the number of pedestrians, maybe in favor of cycling (Mobilität in Deutschland 2019).

2017-2019 Munich Amster Private Car 46 29 18 25 Public Transport 16 21 Walking 15 28 Cycling 2 Other 0 **INNER CITY** 8 34 Private Car 24 17 Public Transport Walking 24 27 18 46 Cycling 2 Other 0

Table 5.2: Modal split of main transport modes (in percent)

The impact of the covid pandemic was similar in the cities, with a decline up to 70-90% in the share of public transport due to the perceived increased risk of infection. Users changed their mode of transport based on their pre-pandemic habits. Those who owned a car used it more frequently and those who relied on public transport switched to cycling or walking. However, there has been an overall decline in private car sales, and it was predicted that OEM and supplier factories would produce 7.5 million fewer vehicles in 2020 (McKinsey & Company 2020).

#### Private vehicles

Levels of road congestion are high in all four cities, with Munich and Oslo particularly high. Oslo has a combined congestion charge and low emission zone (cordon scheme). The cost of the road toll is dependent on the Euro standard of the vehicle and fuel type used, as well as time and distance (Urban Access Regulations 2021).

Munich on the other hand only has a city low emission zone, like Amsterdam and Copenhagen. Onstreet parking rates in the German city center are remarkably low.

Amsterdam, for its part, intends to combat it with high taxes for new vehicles (Wappelhorst 2021), high parking fees (with parking reserved exclusively for electric cars (City of Amsterdam 2021b)) and its progressive expulsion from the city center. The city is also looking for ingenious solutions to influence modal behavior, such as the Pcoins project.

The City of Copenhagen is concerned about the rise in private car ownership due to an increase in the standard of living and a reduction in taxes on new registrations. Therefore, for newly erected residential houses, a maximum of one parking spot per 250 square meters may be built, and new districts are planned to be completely car-free (By og Havn 2021).

In terms of conversion to electric cars, Oslo and Amsterdam take the lead.

dam	Copenhagen	Oslo
	34	35
	18	30
	19	29
	29	6
	0	0
	24	25
	30	42
	5	24
	41	8
	0	1

	Munich	Amsterdam	Copenhagen	Oslo
Congestion level (%)	24	18	18	20
Time lost in rush hour (h/year)	94	64	78	98
Low traffic (days/year)	44	68	38	35
Share of newly registered BEVs(%)	7	14	2	54
Parking price inner city (€/h)	1	7.5	4	3.88

Table 5.3: Traffic characteristics (2020)

#### **Public Transport**

If public transit shares, public transit affordability, annual trips per capita, and station density in the service area are considered, Copenhagen offers better public transport than Oslo or Amsterdam (Wuppertal Institute 2018).

Transport fares in Oslo are slightly higher than in Munich, although Munich has a higher GDP. In the case of Amsterdam and Copenhagen, both cities provide passengers with a transport card, personal or anonymous, to benefit from economic advantages and to offer the traveler a personalized fare according to the distance travelled on each occasion.

Despite lower fares than other cities, Amsterdam still lags behind in terms of public transport. Its current scheme is seen by some as uncompetitive, with a relatively new and improved north-south metro connection supported by trams and buses running perpendicularly (hindering radial routes), but with an incomplete circular line. The visions include a west tangent, an East-West metro line and the closing part of the metro ring. The connections with the airport's area in Schiphol will also be improved with HOV between the Westpoort and Schiphol, and the prolongation of the north-south metro line (City of Amsterdam 2021).

#### Air quality

As far as air quality is concerned, Amsterdam and Munich lag noticeably behind. The best values are in Copenhagen, closely followed by Oslo. However, all three studied cities have set ambitious targets: in the case of Amsterdam to be emission-free by 2025, in the case of Copenhagen to become carbon neutral by 2025; and in the case of Oslo to be fossil fuel free by 2030. Since 2014, the proportion of diesel cars has been decreasing in Oslo, which may help to reduce N02 levels. However, the high percentage of car use in Oslo threatens the city's air quality targets. Due to the big push for electric cars, pollutant levels in Oslo and Amsterdam are expected to be significantly reduced in the coming years.

#### Road safety

Norway has a higher fatality rate for cyclists than Germany. For Denmark the situation improves considerably, and for the Netherlands it improves slightly. However, for pedestrians, the situation in Denmark is the worst of the four countries, followed by the Netherlands. Norway and Germany have the best ratios for pedestrians.

	2021	Munich(€)	Amsterdam (€)	Copenhagen(€)	Oslo(€)
	Anonymous Card	-	20.00	10.4	-
1Zone	Single Ticket	3.40	3.20	3.12	3.69
	Daily Ticket	7.90	8.50	10.40	11.06
	Weekly Ticket	17.80	37.00	39	31.04
	Monthly Ticket	57.00	53.90	53.30	77.12
	Yearly Ticket	684.00	539.00	-	771.15
All Zones	Single Ticket	13.60	-	6.24	13.00
	Daily Ticket	14.20	-	10.40	25.03
	Weekly Ticket	68.40	-	39	75.08
	Monthly Ticket	219.50	-	93.6	196.42
	Yearly Ticket	2,634.00	-	-	1,964.25

Table 5.4: Public transport's tickets and prices

	Munich	Amsterdam	Copenhagen	Oslo
CO2 (Mt)	9.7	4.5	1.3	1.44
PM 2.5 (µg/m3)	12.7	12.9	4.4	8.6
NO2 (µg/m3)	27.3	35.9	5	22.5

Table 5.5: Emission comparison (2020)

	Germany	Netherlands	Denmark	Norway
Cycling share (%)	11	27	22	4
Cycling fatalities ratio	0.043	0.041	0.025	0.056
Pedestrian share (%)	22	18	5	15
Pedestrian fatalities ratio	0.028	0.058	0.124	0.013

Table 5.6: Overview of cycling, and pedestrian share and fatalities ratios (2016, 2017, 2018); Ratio = fatalities / (1000 inhabitants \* modal share)

#### PROJECTS

#### Public mobility, Mobility as a Service and Software Solutions

The observed projects show a great variety of topics around public mobility, software solutions and applications in all cities. The projects in Amsterdam include a crowd management system for pedestrians and cyclists and a mobility coin project as incentive to use less car traffic. For Copenhagen, different measures on the integration of cycling in public transport have been assessed, and for Oslo, autonomous shuttles have been examined. For Munich, two applications to book multimodal or electronic tickets have been observed.

### Vehicle technology and energy

Especially for urban mobility, electric vehicles play a major role in the future of traffic. While Oslo proclaims to have the highest share of EV in the world, Amsterdam boasts the highest density of charging stations. Also, for vehicle technology and energy projects, the research showed a great variety of projects in the cities examined. Charging technology for electric vehicles is an important issue in all cities, but there are several different ways to tackle challenges in this field. In all three cities, projects to increase the density of charging stations were examined. Here, Oslo's GreenCharge project aims to provide charging points for local residents, complemented by the project SEEV4-City, which installs charging stations in parking garages to save public space, improve the use of these buildings, and increase the number of charging points in the city. The project Battery High-Power Charging in Copenhagen offers possibilities to install more charging stations by offering a modular, easy-to-install system, which can offer high-power charging without the need for a high-power grid at the location. Furthermore, especially if the share of electric vehicles increases, smart charging becomes more important to reduce the peak load in the grid, tackled, among others, also by Flexpower in Amsterdam. Besides classical charging while parking, Elonroad from Greater Copenhagen offers an electrical road to extend the range of electric vehicles, especially also for public mobility.

The share of energy from renewable sources in 2019 was 17,35% in Germany; 8,76% in the Netherlands; 37,20% in Denmark and 74,62% in Norway (Eurostat 2021). To increase this share further, different technologies also in the electric vehicle charging sector can be used. Here, several charging stations of projects assessed support vehicle-to-grid technologies for energy storage. Moreover, the Johan Cruijff Arena Battery Storage in Amsterdam serves as a large-scale energy storage to store unused renewable energies when the energy demand is too low.

Besides the electricity supply and charging technologies, also other topics are covered by the projects assessed. The projects examined in Munich try to improve automated driving, both for private vehicles and public transportation. Here, a test road to try new features of autonomous cars in urban traffic and the perception of citizen are being evaluated. For the GeoSUM project in Oslo, a tool to reduce the share of petrol cars using geofencing is assessed. With this tool, also additional information which is relevant for traffic can be given to drivers, e.g., on nearby schools or accidents.

#### Active mobility

In the case of active mobility, both Copenhagen and Amsterdam are battling it out for first place, leaving Oslo and Munich behind.

In both cities, although the preferred mode of transport for commuting to work is the bicycle, citizens mostly opt for the car at the weekend for recreational purposes or to visit loved ones, challenging the cyclist-friendly environment. Another similarity between the two cities is the fact that the cycling network is reaching its maximum capacity due to its great popularity in recent years.

It is also worth mentioning the small proportion of pedestrians in Amsterdam, which is influenced by the heavy traffic and the small sidewalks in the city center, where active modes are predominant.

As for the projects in Amsterdam, the practical Dutch approach stands out, as the projects seek to address real serious problems that the city is facing, such as congestion on the cycling network and

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theft. Copenhagen, however, adopts a more theoretical position, where knowledge transfer and best practices are sought.

Oslo, on the other hand, focuses on the development of its cycleways and its efficient bike sharing system.

Munich cycling infrastructure is improved due to two referendums initiated by citizen movements. During the pandemic, the cycling network grew significantly through pop-up bike lanes to accommodate the modal shift from public transport. However, many of these lanes were dismantled during the winter.

#### Urban planning and public spaces

All cities face the challenge of accommodating many new residents in the coming years. With gentrification, rental prices in the city center become unaffordable for a large part of the population. In the absence of an urban planning strategy, this could lead to social inequalities.

In the case of Amsterdam, instead of expanding into its surrounding green welt, but by inventively increasing housing density (52,500 new homes by 2025) and transforming existing built-up areas within the city limits, like the harbor. In addition, in the coming years, the connection to the northern shore of the city (absorbed by the city in the last century) will be improved, overcoming the natural barrier of the river and the technical difficulties faced up to now. The aim is to increase accessibility for active modes with footbridges (City of Amsterdam 2021d).

In the case of Copenhagen, it also follows the same strategy of redeveloping the old harbor area (Nordhavn), creating a multifunctional area (40,000 new homes by 2060).

On the other hand, Oslo is focusing on redeveloping an industrial area (Hovinbyen) near the city center due to its strategic location with a fifty-year perspective (City of Oslo 2021). Oslo also began pedestrianization of some of its streets in the city center with the aim of reducing heavy car use.

The numbers of jobs and tourists are also rapidly growing. Public space's scarcity is a common problem in the three cities.

In the case of Copenhagen, this represents particularly a big problem due to the already existing high efficiency of public space. In addition, the city is investigating the creation of fully climate-adapted spaces that support biodiversity and are resilient to climate change.

Oslo is on the path to making its city center car-free. In addition to the many advantages for active modes, this has led to the conversion of car parks into public space, improving livability and quality of life in the city.

For its part, Amsterdam has put a special focus on public space due to its scarcity. By 2030, Amsterdam wants to achieve a car-free center and improve the situation for the sometimes-forgotten pedestrians by channeling cyclists. Moreover, more parking garages will be constructed under the canals to free up space (City of Amsterdam 2021e). On the other hand, Amsterdam has developed an instrument (ATOR) to render public space measurable and monitor the improvements on its aim to achieve a sustainable, functional, and pleasant public space (City of Amsterdam 2021f).

Munich is also considering converting its city center into a car-free center. In addition, through experiments, it is seeking to encourage the use of more sustainable means of transport. In addition to reducing congestion on the road network, this will free up public space, which has great potential to improve the quality of life for citizens.

## **Co-creation**

All cities seek to become more inclusive and livable. For this, citizen participation becomes essential. Therefore, both in Copenhagen and Oslo as well as in Munich different institutions and initiatives aim to foster interaction between different players in economy, society, and academia. For Amsterdam, the observed projects focused mainly on citizen engagement. In Oslo and Copenhagen, this exchange between stakeholders is to be reached with institutions as Innoasis (Norway) and BLOXHUB (Denmark), where various firms and other parties can work in a shared office space, with further offers to exchange ideas and to communicate. The Munich Urban Colab provides a similar offer. Additionally, the MCube cluster for mobility research and innovation involves all relevant Munich actors in the field. Amsterdam has a long history of bottom-up initiatives, since the 1970s with the construction of the GWL Terrein through a participatory process. However, citizens are nowadays expressing a disengagement from authorities. Amsterdam wants to reverse this trend by promoting citizen participation in the replanning of public space with projects like Model 3D. In addition, the city sets aside funds for citizen proposals.



# CONCLUSION

To summarize the research presented in this report, this last chapter will highlight the major trends in urban mobility innovation that could be identified across the cities of Amsterdam, Copenhagen, and Oslo, as well as highlighting specific measures that stood out, be it due to their impact on mobility in the City of the future, their applicability to the challenges faced by the City of Munich or their uniqueness compared to the other cities. All measures are categorized in the five fields of public mobility, vehicle technologies, active modes, urban planning, and co-creation and will be presented this way in the summary.

Amsterdam, Copenhagen, and Oslo all proved to be global leaders in different aspects of urban mobility innovation. At the same time, all cities showed uniqueness. Be it in the way their city's mobility is structured, the way it grew historically or in their approach to innovate for the City of tomorrow. The research focused on such measures for innovation, trying to understand their impact on the city's mobility and analyzing their potential to be adapted for similar challenges that the City of Munich is currently facing. Being the global leaders that they are, all three cities have measures in place that are in one way or another a step ahead of Munich. This has a lot of potential for the City of Munich to learn from the experiences of the other cities and from the challenges they faced implementing innovative measures.

#### Major Trends & Measures

All four observed cities - Amsterdam, Copenhagen, Oslo, and Munich - are making a great contribution to sustainable development and advancing the guality of life for its residents. Despite the differences in cities' size, demographics and geographical location, the observed cities are facing the challenges of high urbanization rate, increasing CO2 emissions, traffic congestions and environmental changes. Providing more mobility solutions is one of the ways to successfully handle mentioned problems. Based on conducted research, observations, interviews, and cross-city analysis there were identified several common tendencies implementing by the cities to offer higher level of urban mobility.

Implementation of environmentally friendly vehicles and sufficient infrastructure for it. Green vehicles running on on battery electric power are becoming an important component of cities daily life. Market share of electric vehicles are constantly growing in a worldwide perspective being promoted by political initiatives and awareness of environmental challenges. European countries are massively contributing to using more green vehicles through introducing it in operating public transport lines, e-scooter and car sharing services. The number of countries provide subsidies and lower taxes for electric vehicles to boost low-emission mobility. Moreover, there are great investments into charging infrastructure to assure the proper balance of charging points as well as accessibility to them (Urban Insight, 2018). Currently, all four cities are taking the leading positions in increasing electric vehicles market share in following order: Oslo, Amsterdam, Copenhagen, and Munich (VDA 2021).

**Promoting alternative modes of transport – active mobility**. Walking and cycling are affordable efficient ways to support climate-neutrality strategies. In combination with public transport, walking and cycling can cover almost all mobility needs within the city and suburban areas (ICLEI 2020).

Amsterdam and Copenhagen are considered as Europe's cycling capitals characterized by a great number of trips made by bikes. Followed by Munich and Oslo, all observed cities are focusing on upscaling active mobility to reduce greenhouse gas emissions, resolve the first/last mile problem and influence on public health. Moreover, the strong urge for it raised in 2020 when the Covid-19 pandemic started. The local governments had to consider new and fast solutions (such as widening cycling lanes, pup-up bicycle lanes etc.) into significant demand and shifts to cycling and walking infrastructure (Pardo & Combs 2021).

**Continuously shaping urban areas and public spaces.** Facing the challenges of population growths, climate changes and Covid-19 pandemic, nevertheless, considered cities are striving to create inclusive, safe, resilient, and sustainable areas for its residents to satisfy their needs. Furthermore, successful implementation of urban mobility projects often goes along with district redevelopment. A big number of urban projects are oriented on shifting city's districts into multifunctional areas with diverse mobility options as well as public spaces. Following this idea can help to reduce the number of long-distance trips (usually made by car) and create places for social interaction. Apart from it, nature-based projects are helpful to react to current and future climate changes as well as creating enjoyable living districts.

Prioritizing efforts towards sustainable urban mobility resolves not only the issues of noise and air pollution but also helps to make cities greener, adjusting to environmental changes and great places to live.



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### Thank you!

Special thanks to the project supervisors Carolin Zimmer, Sophia Knopf, and Daniel Schröder for creating an interdisciplinary framework, which allowed us to write this report and explore cities leading in urban mobility.

Furthermore, we want to thank our interview partners. With your help, we got an insight into how the cities work on a day-to-day basis, what is next, and which challenges remain.

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