Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Architecture and Planning

Elham Abdollahzadeh

The role of urban planners in smart urban mobility; case study of Nyhavna, Trondheim

Master's thesis in Urban Ecological Planning
Supervisor: Yu Wang
Co-supervisor: Dirk Ahlers
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Acknowledgements

This thesis is the result of my interest in Urban Ecological Planning. I am grateful for my thirst for learning which kept me motivated throughout the thesis.

I would like to thank my family, who have always supported me in following my dreams.

Special thanks to my supervisor Yu Wang and my co-supervisor Dirk Ahlers, who were always supportive and understanding. I am grateful for their guidance and valuable feedback.

Finally, I would like to remind myself of the days I stopped writing the thesis when wars and violence brought grief and darkness to the world, whether in my precious home country, Iran or in Ukraine. I hope and trust that the most prolonged and darkest nights are followed by light.

Abstract

The shift to the new era of smart cities has begun over a decade, and the new transformations are inevitable. Transportation planning is a crucial aspect of planning for the cities and has been influenced by this transition. With respect to planning for an urban transportation system, there is a gap between urban planners' solutions to transportation problems and data-driven smart city solutions. This research aims to bridge the current smart city trend to urban planning. Urban planners should reach out for the available big data that is useful for the planning process and adopt the technology to collect the data they need. It is important to investigate how this data can be useful to optimise planning solutions. Technology can increase the speed of processing data with less mistake rate, which makes it more efficient and much cheaper. Urban planners can be creative to avoid falling behind the smart city transition.

On the other hand, smart cities are mainly pursuing ICT and IoT-based solutions, neglecting the fact that cities are like living creatures. Cities are relatively diverse and not easily predictable. The analysed data for each city and each neighbourhood could be interpreted differently. Therefore, urban planners should localise the criteria to assess each dataset. Inspecting human behaviour and culture to reach more compatible results. In addition, an important role of urban planners is to make sure that cities are inclusive, considering that not everyone can use technology equally.

This essay is analysing the Nyhavna district in Trondheim as a case study of smart urban mobility. Nyhavna has been a port area of Trondheim with industrial use for decades. This area is missing the potential to be used as an active, livable neighbourhood that connects the city centre to the fjord. Therefore, there has been extensive research undergoing for the new development of Nyhavna. Reflecting on Nyhavna as a pilot project considering the needs of smart cities before the developments can be relevant research since smart cities could extract the required data if the cities were planned to be smart in advance, and urban infrastructures could have been designed differently to meet the needs of smart urban planning. In this case, big data can help urban planners identify and solve urban problems faster and cheaper. The data can be provided by companies, research groups, and, most importantly, citizens. It is not clear if urban planners are ready to be smart. There are questions to be investigated further, such as: what are the problems that urban planners can solve using big data, what data are required, how to analyse the data, and how eventually it can help urban planners to predict the consequences of their decisions.

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List of Abbreviations

AEGIS	Advanced, Efficient and Green Intermodal Systems
AV	Automated Vehicle
BRT	Bus Rapid Transit
CCTV	Closed-circuit television
DOGA	Design og (and) Architecture
DPEB	Distributed positive energy block
DSB	The Norwegian Directorate for Civil Protection
EV	Electric Vehicle
GHG	Greenhouse Gas
GIS	GIS in Transportation (GIS-T)
GPS	Global Positioning System
ICT	Information and Communications Technology
ITS	Intelligent Transportation Systems
KPIs	Key Performance Indicators
MaaS	Mobility as a Service
NTNU	Norwegian University of Science and Technology
PEB	Positive Energy Block
SATS	Sustainability Aware Travel Service
SINTEF	Stiftelsen for Industriell og Teknisk Forskning
SUL	Smart urban logistics
SUMP	Sustainable Urban Mobility Plan
SWOT	Strengths Weaknesses Opportunities Threats
TNMT	Travel and Mobility Tech
TOD	Transit-Oriented Development
UNFCCC	United Nations Framework Convention on Climate Change
V2B	Vehicle to Building
V2G	Vehicle to Grid
ZEB	Zero-Emission Building
ZEN	Zero-Emission Neighborhood

1 Introduction

1.1 Overview

Smart urbanisation is now taking place in hundreds of cities around the world through urban projects, strategies, and ambitions. Karvonen *et al.* (2019) discuss how local governments, small and medium businesses, companies, utility providers, and civil society organisations collaborate to build smart cities at the neighbourhood, city, and regional levels. Based on the report of Smart cities ranking of European medium-sized cities (2007), smart mobility (transport and ICT) is one of the sixth characteristics of a smart city. Smart urban planning by applying big data using computer simulation can be used to predict future mobility needs and evaluate the consequences of different decisions. This research investigates the role of urban planners in the smart urban mobility field through the case of Nyhavna.

1.2 Problem statement

Generally, urban planners are open-minded to interdisciplinarity, even though they are usually graduated in a certain discipline. It is very difficult for urban planners to disregard the numerous approaches toward urban issues developed by other disciplines. Urban planning requires an accurate appropriation of what has been discovered in other fields, as well as an up-to-date identification of what constitutes the city (Pinson, 2004). Smart urban mobility solutions are being implemented while urban planning addresses mobility issues in parallel but not in coordination with smart mobility trends.

Unfortunately, within planning for smart urban mobility in smart cities, the main focus is on the digital infrastructure and the urban planner's role is disregarded. Smart technologies give city actors the ability to collect and exchange data, which can be used to inform existing decision-making processes and, hopefully, make cities more sustainable, resilient, and livable. According to the data presented in this thematic issue, the question of who or what controls the smart city is still being debated. Finally, this serves as a warning for urban planners to engage the smart city fully. In this process, planners and planning practices have been neglected (Karvonen *et al.*, 2020). The "Roadmap for smart and sustainable cities and communities in Norway" has mentioned the lack of connections and cooperation with other planning work/focal areas (such as digitalisation and urban planning) is a challenge and obstacle that prevents the development of successful smart cities (NordicEdge *et al.*, 2020).

Ahlers (2020), in his paper about the challenges of sustainable urban mobility integration, states that a Smart city is comprehended as a deep collaboration between citizens and technology. The extensive range of actors, stakeholders, and service providers we can co-create solutions with, are aimed to be considered in sustainable urban mobility integration. However, we do not yet know how this collaboration will play out in many scenarios.

Urban planners should give special attention to the contributions they make to the building of places that are more suitable for everyday living. In the meanwhile, they should stay receptive to contributions from other disciplines in order to attain this aim (Pinson, 2004).

Overall, the importance of the collaboration mentioned above has been noticed, but it is not widely argued in scholarly documents. However, it makes finding relevant literature that supports this idea even more challenging.

With respect to the mentioned concern, Trondheim city as a new smart city with several smart urban projects in progress is a valid context to be investigated from an urban planning perspective in this essay.

1.3 Background of the research

Based on the UNFCCC (2020) report on Norway's long-term low-emission strategy for 2050, the Ministry of Climate and Environment considered funds, including grants to reduce emissions from commercial transport through zero-emission solutions, which was launched in the summer 2019. Only the agreement covering Trondheim and its environs has been finalised so far. These agreements are intended to help achieve the goal of zero-growth in passenger car traffic in the main urban regions, as well as to ensure that land-use planning and the development of public transportation, pedestrian and cycling pathways are coordinated.

Nyhavna is a developing neighbourhood located in the Trondheim port area. The main function of the area is industrial and port activities currently, but it is planned to be a mixed-use neighbourhood with residential units along with social and commercial activities. Although the proposed plans are in the assessment stage and not approved yet, the current plans, including the "Nyhavna municipal sub-plan" and "Quality program of Nyhavna", are used in this research. This case is selected since the main goals of future developments are aligned with the smart urban mobility goals that are discussed in this research. Based on the Trondheim municipality (2020), offering future-oriented mobility and establishing Nyhavna as a pioneering example of the zero-emission society of the future are examples of the strategies to be followed in the planning process.

1.4 Aims and objectives of the thesis and research questions

It is expected that discussing smart urban mobility for Nyhavna from an urban planning perspective will shed light on the gaps that urban planners are able to fill in the planning process of the smart cities and smart transportation planning in Trondheim to have a safer, more accessible, and more sustainable mobility.

Research Question

- ***Should urban planners have a role in planning for smart urban mobility?***
- ***How can urban planners contribute to smart urban mobility?***

Sub-question:

- ***How can urban planners employ smart urban mobility solutions?***
- ***How can urban planning prepare the ground to develop smart urban mobility in Nyhavna?***

The first two questions aim to find out if urban planners can enhance smart urban mobility solutions and how it is possible. However, it is important to investigate if the role of urban planners in this process is neglected in the first place. The literature review in this essay is first trying to find out the current role of urban planners in the smart cities trend.

This research is not limited to the influence of urban planners on smart urban mobility solutions. The sub-questions are structured to see this cooperation from the opposite side as well. This means the influence smart urban mobility solutions can have on urban planning will be considered on top of that. The last sub-question is designed to use fieldwork to check if the fieldwork findings support the idea that is questioned earlier in the first research question.

1.5 Structure of the thesis

This thesis is fieldwork-based, which combines the theories introduced in the research background with the findings from the fieldwork.

For achieving the objectives mentioned above, existing knowledge is investigated in the theory chapter. First, the idea of a “Smart city” is explained, and then smart urban mobility is introduced. Later, three urban concepts of “Low-carbon cities”, “Zero-emission neighbourhoods”, and “15-

minute city", with a focus on urban mobility's role in these concepts, are explained. After, examples of the technologies that are used for mobility planning are given. The existing knowledge forms the basic knowledge that will be used further in this essay. The theory chapter also investigates the previous studies that were developing a framework or set of factors to evaluate smart urban mobility. These factors are reviewed, and a smart urban mobility framework is suggested at the end of the Theory chapter.

The next chapter describes the methodological approach applied to develop the essay. The data collection methods are explained in detail, including the case study data gathering. In the end, the challenges and limitations that hindered the data gathering process are mentioned.

The fourth chapter investigates the context of the case study. Viewing the study area further is scale and time; Nyhavna is demonstrated in the Trondheim context along with its history and identity. Then the current studies and plans that provide the required information for planning for the future of Nyhavna, as well as other companies directly involved with Trondheim mobility, are noted.

In the next chapter Nyhavna as the case study of this thesis, is analysed according to the framework. The framework uses sustainability, traffic management, safety and infrastructure as the main factors to explore the smartness of urban mobility in Nyhavna.

Finally, the last chapter of the thesis provides the findings and implications. First, the analysis and reasonings are discussed. Then, all pieces are argued as a whole to connect all the gathered data. Recommendations are given based on the argument later. All the related questions that were beyond the scope of this thesis but could help with developing the idea are provided for further investigation. Eventually, the thesis is summed up in the conclusion chapter.

2 Theory

This chapter discusses previous studies and the relevant urban planning theories and trends. In the second sub-chapter, previous related frameworks are introduced, and finally, a smart urban mobility framework is suggested.

2.1 Research background

For all research fields and projects, prior, relevant literature must be taken into account. When reading an article, the author begins by discussing past research to map and analyze the research area, inspire the study's goal, and explain the research question and hypotheses, regardless of discipline. The "literature review," "theoretical framework," or "research background" are all terms used to describe this section (Snyder, 2019).

2.1.1 smart city

There are various definitions of the smart city since it is a new concept. The roots of smart cities go back to the discussions among scholars during the 1980s, arguing about the future of the cities. The concept was described in phrases such as *the age of technopolis*, or *intelligent city* with a complicated network of information and communication (Glasmeier *et al.*, 2015).

Hall *et al.* (2000) believe the integration of science and technology through information systems is crucial to a picture of the future city. A future that will necessitate a rethinking of how government, city administrators, business, academics, and the research community interact.

Based on the definition of the smart city in the report of Smart cities ranking of European medium-sized cities (2007), a smart city is performing well in six characteristics of the smart economy, smart people, smart governance, smart mobility, smart environment, and smart living, in a forward-looking way and smart combination of activities of independent, aware citizens.

Harrison *et al.* (2010) suggest that smarter cities are urban areas that use operational data to optimise the operation of city services that are extracted from traffic congestion, power consumption statistics, and public safety incidents and the fundamental concepts are Instrumented, linked, and intelligent.

Nam *et al.* (2011) describe smart cities from an urban innovation point of view. They suggest a smart city can be thought of as a contextualised interplay between technology innovation, managerial and organisational innovation, and policy innovation because each city’s unique setting determines its technological, organisational, and policy features.

The definitions of smart cities are manifold, and there are various characteristics to define smart cities. Giffinger *et al.* (2007) suggest factors to define each characteristic of the smart city in Table 1.

Caprotti *et al.* (2016) suggest that "smart" might reflect different definitions from city to city. In some cases, it refers only to data-driven governance solutions or to a specific industry (for example, transportation); in others, it refers to a broad range of environmental, social, and economic goals and may include specific initiatives that have little to do with the potential benefits of digital technology adoption.

SMART ECONOMY (Competitiveness)	**SMART PEOPLE (Social and Human Capital)**
▪ Innovative spirit ▪ Entrepreneurship ▪ Economic image & trademarks ▪ Productivity ▪ Flexibility of labour market ▪ International embeddedness ▪ ***Ability to transform***	▪ Level of qualification ▪ Affinity to life long learning ▪ Social and ethnic plurality ▪ Flexibility ▪ Creativity ▪ Cosmopolitanism/Open-mindedness ▪ Participation in public life
SMART GOVERNANCE (Participation)	**SMART MOBILITY (Transport and ICT)**
▪ Participation in decision-making ▪ Public and social services ▪ Transparent governance ▪ ***Political strategies & perspectives***	▪ Local accessibility ▪ (Inter-)national accessibility ▪ Availability of ICT-infrastructure ▪ Sustainable, innovative and safe transport systems
SMART ENVIRONMENT (Natural resources)	**SMART LIVING (Quality of life)**
▪ Attractivity of natural conditions ▪ Pollution ▪ Environmental protection ▪ Sustainable resource management	▪ Cultural facilities ▪ Health conditions ▪ Individual safety ▪ Housing quality ▪ Education facilities ▪ Touristic attractivity ▪ Social cohesion

Table 1:Characteristics and factors of a smart city (Giffinger et al., 2007)

In the Norwegian context, as is stated in the national roadmap for smart and sustainable cities and communities in Norway (2020), a smart city is defined as cities and communities with their focus on people while applying new technologies, innovations, participatory and co-creation methods to grow more sustainable, productive, attractive, and resilient. The national roadmap suggests eight principles for smart and sustainable cities, as can be seen in figure 2.

Karvonen *et al.* (2020) define today's smart city agendas as the newest incarnation of urban sociotechnical innovation. Their goal is to employ information and communication technology to help cities enhance their economic and environmental performance while also improving citizens' quality of life.

Figure 1: Eight principles for smart and sustainable cities and communities (NordicEdge et al., 2020)

2.1.2 smart urban mobility

Smart transport/mobility is one of the six main elements in a smart city, which aims to enhance accessibility, sustainability, safety and other factors (Giffinger *et al.*, 2007).

Smart mobility is a term used to describe the various aspects of the digital transformation of transportation and mobility systems. "Zero Emissions, Zero Accidents, Zero Ownership" is one way to put it (Neckermann, 2015).

Transportation that is fast, safe, and efficient contributes significantly to the development of smart cities. The goal of the Intelligent Transportation System is to utilise cutting-edge technology to create more intelligent roads, cars, and users (Sadanandan *et al.*, 2017).

Emerging transportation solutions have lately emerged that completely change current urban mobility modes and associated modelling paradigms for single-modal and multi-modal transportation, private and public transportation, land and sea transportation, and passenger and freight transportation (Qu *et al.*, 2021).

Finger *et al.* (2019) introduce four turning points of new fuel systems, communication and information technologies (ICTs), smart cards, and new consumption patterns relying on users rather than traditional ownership might help to progress towards a "post-car" system that is more sustainable than the current one.

A "Sustainable Urban Mobility Plan" is a strategic plan designed to meet the mobility requirements of people and businesses in cities and their environments to improve quality of life (Rupprecht Consult, 2019).

Traditional Transport Planning		Sustainable Urban Mobility Planning
Focus on traffic	→	Focus on **people**
Primary objectives: Traffic flow capacity and speed	→	Primary objectives: **Accessibility** and **quality of life**, including social equity, health and environmental quality, and economic viability
Mode-focussed	→	**Integrated development of all transport modes** and shift towards sustainable mobility
Infrastructure as the main topic	→	**Combination** of infrastructure, market, regulation, information and promotion
Sectoral planning document	→	Planning document **consistent with related policy areas**
Short and medium-term delivery plan	→	Short and medium-term delivery plan embedded in a **long-term vision and strategy**
Covering an administrative area	→	Covering a **functional urban area** based on travel-to-work flows
Domain of traffic engineers	→	**Interdisciplinary** planning teams
Planning by experts	→	Planning with the **involvement of stakeholders and citizens** using a transparent and participatory approach
Limited impact assessment	→	Systematic **evaluation** of impacts to facilitate **learning** and improvement

Table 2: Comparing traditional transport planning and Sustainable Urban Mobility Planning (Rupprecht Consult, 2019)

Sustainable Urban Mobility Plan relies on existing planning processes while also considering principles of integration, participation, and assessment. In contrast to traditional planning approaches, sustainable urban mobility plan (SUMP) emphasizes citizen and stakeholder participation, policy coordination across sectors (particularly transportation, land use, environment, economic development, social policy, health, safety, and energy), and broad collaboration across government layers and with private actors (Rupprecht Consult, 2019).

Urban planning has always been inextricably linked to technological advancement. Planners have been tasked with mediating and aligning society and technology to build contemporary cities since the advent of nineteenth-century infrastructural networks to the introduction of vehicles, streetlights, spatial analysis tools, personal computers, and the World Wide Web. Although smart city agendas are "trying to challenge old concepts and practices of planning," urban planners have had a surprising lack of influence (Karvonen *et al.*, 2020). The empirical findings reflect the wide range of current smart city applications, shifting the focus of smart city research away from its technological promise and toward its practical application (Karvonen *et al.*, 2019). Based on a diverse range of smart city applications, Caprotti *et al.* (2016) claim that just under a third of UK cities with populations of over 100,000 had a clear "smart-eco" objective and/or significant related projects underway.

Karvonen *et al.* (2020) claim that for far too long, the smart city agenda has ignored planners and planning methods; it is time for that to change.

New apps on the cutting edge of digitised transportation will play an increasingly important role in urban mobility. Mobility technology, on the other hand, has an impact on more than only mobility practices and user behaviour. They can also help cities with transportation and mobility planning (Lenz *et al.*, 2017).

For strategic urban transportation system planning, new mobility services that promote multimodal alternatives are critical. Municipal investments in urban mobility hubs are part of this plan to expand access to mobility services (Tran *et al.*, 2021).

Human infrastructure is emphasized, with a focus on social learning and education. The human capital aspect of the transportation system should start with people in order to create more progressive smart cities. A smart mobility solution is more than just saving energy or using ITC; it is also about being able to act as part of a bigger system that includes participation, urban and space quality, human capital, education, and learning in urban settings. A desire to change is required, as well as an acknowledgement of communal responsibility. It's critical to develop an environment that encourages constant learning and innovation (Papa *et al.*, 2015)

Papa *et al.* (2015) describe the interrelations between sustainability smartness and quality of places and state that these relations should be strengthened in theory and in practice at the same time. The mentioned links are illustrated in figure 2.

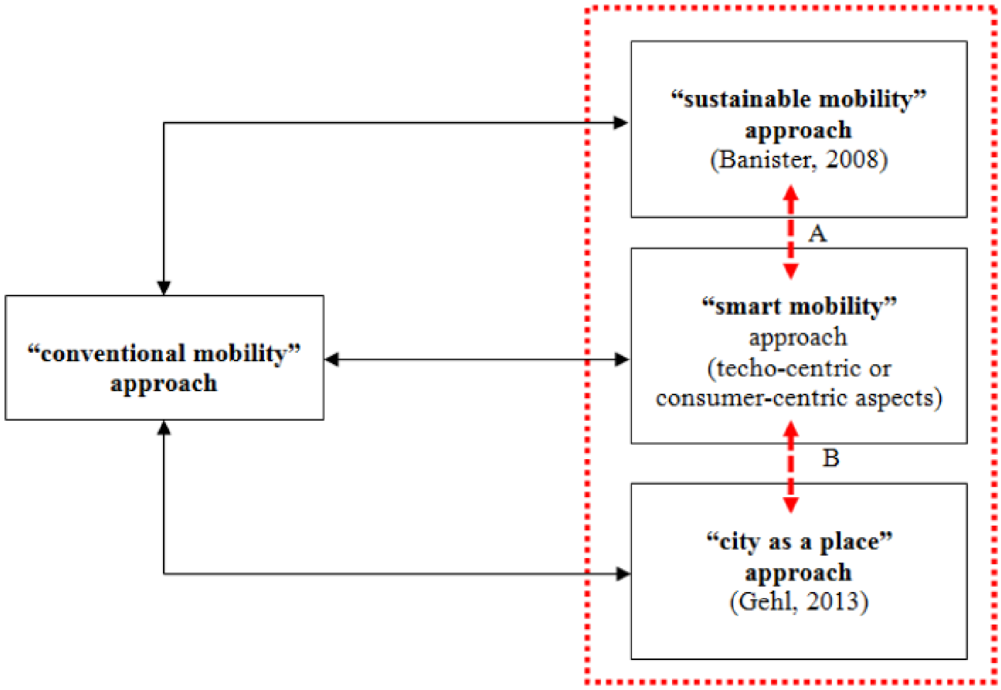

Figure 2: The approaches to mobility planning and their missing links (Papa et al., 2015)

2.1.3 Urban mobility in low-carbon cities

It is generally not enough to put in place physical infrastructures such as a public network of EV charging stations, an integrated network of segregated bicycle lanes, or a BRT system to fairly decrease GHG emissions from urban transportation operations. It's also important to understand how people with diverse talents, views, and (previous) experiences use such infrastructures. The same is true of discursive construction: an integrated cycling network may not convert into cycling functioning for many people if it is just portrayed as a means of commuting quickly and reliably to and from work or as a way to improve physical fitness. Advocates may reveal the myopia - and egoism - of such reasoning by demonstrating how fewer (very polluting) vehicles on city streets might improve the cycling capabilities of non-car users on those same routes. Furthermore, converting such abilities into observable cycling might lead to imitation and group safety. As a result, socially inclusive, self-reinforcing trajectories of expanding cycling capacities and functions across a city's population, including (former) vehicle drivers, might emerge (Schwanen, 2021). In table 3, Gouldson *et al.* (2015) suggest low-carbon actions analysed in the economic analysis.

Transport	
Urban planning and reduced passenger travel demand	Land use planning reduces motorised passenger travel activity (pkm per capita) by as much as 7% in OECD countries and 25% in developing countries.
Passenger mode shift and transit efficiency	Expansion of public transport leads to 20% lower pkm mode share of light-duty vehicles (LDVs) and higher mode share for rail and bus transport.[16]
Passenger car efficiency and electrification	A combination of more efficient and electric private vehicles results in >45% improvement in private vehicle efficiency globally. The energy intensity impact of electrification is based on the 2DS scenario variant Electrifying Transport [17] and *Energy Technology Perspectives*.[18]
Freight logistics improvements	Freight transport logistics improvements lead to a 5% reduction in tkm per capita by 2030 and 12% by 2035.[19]
Freight vehicle efficiency and electrification	Global freight energy efficiency improves by 17% by 2030, and by 26% by 2050. In addition, 27% of global freight is electrified by 2050.[20]

Table 3: Low-carbon actions analysed in the economic analysis (Gouldson et al., 2015)

In the low-carbon era, optimising the spatial structure of cities to support low-carbon transportation is a primary objective of urban planning and construction innovation. A basic study is required on the structural characteristics that aid in minimizing motor traffic and, by that means, promoting energy conservation. The distribution of residential, business, retail, and recreational zones, as well as leisure amenities, across an urban area, shapes the activities of residents and, as a result, affects their travel needs both in direct and indirect ways. (Ye *et al.*, 2018).

Ye *et al.* (2018) name the factors influencing travel behaviour and transport emissions cited by Pan (2014) and Ratti *et al.* (2005), which are as follows:

1. form factors including the urban compactness, density and scale,
2. function factors such as the mix of land use,
3. network factors such as the land use/transport connection.

Cervero (1995) stated that Stockholm had transformed itself into a multi-centred city with a minimal degree of car dependency by consolidating the new urban developments into high-density forms clustered around rail stations over the last 50 years.

Grazi *et al.* (2008) and Mindali *et al.* (2004) suggest that travel demand can be minimized by clustering of the housing units and business activities into nodes. The increase in private vehicles can be reduced by increasing residential and employment density near public transportation hubs and consequently increasing public transit usage. Many cities, including Stockholm, Copenhagen, Toronto, Singapore, and Hong Kong, have successfully experimented with land use/transport interactions, resulting in the creation of a sustainable form of transportation and land use (Ye *et al.*, 2018).

The TOD paradigm, which has been highly effective in developing compact and very high-density urban development concentrated around rail transit stations, has been exactly followed by contemporary transit metropolises such as Singapore, Hong Kong, and Copenhagen. The traditional TOD model, on the other hand, emphasizes the need to manage urban growth through public transportation and 3-D planning variables, which are insufficient. It partially neglected the organic linkage between urban growth, public transportation, and the green space system, as well as the critical importance of non-auto travel modes and their organic interaction with public transit (Ye *et al.*, 2018). The traditional TOD model is illustrated in figure 3 (Calthorpe, 1993).

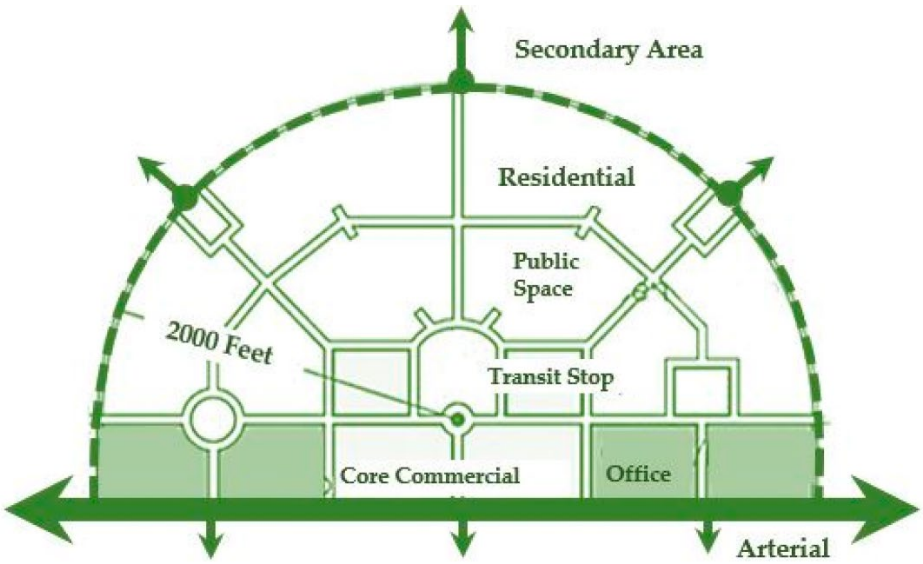

Figure 3: The concept of TOD (Calthorpe, 1993)

To further investigate the level, choosing different transportation modes can lead us to lower carbon emissions; a comparison is provided below.

All major urban transport modes are ranked based on their carbon-emission output, which is illustrated in figure 4. The ranking is suggested by TNMT, which is an industry working on digital innovation in the context of travel and mobility. The industry is led by the team of Research & Intelligence of the Lufthansa Innovation Hub (TNMT, 2021).

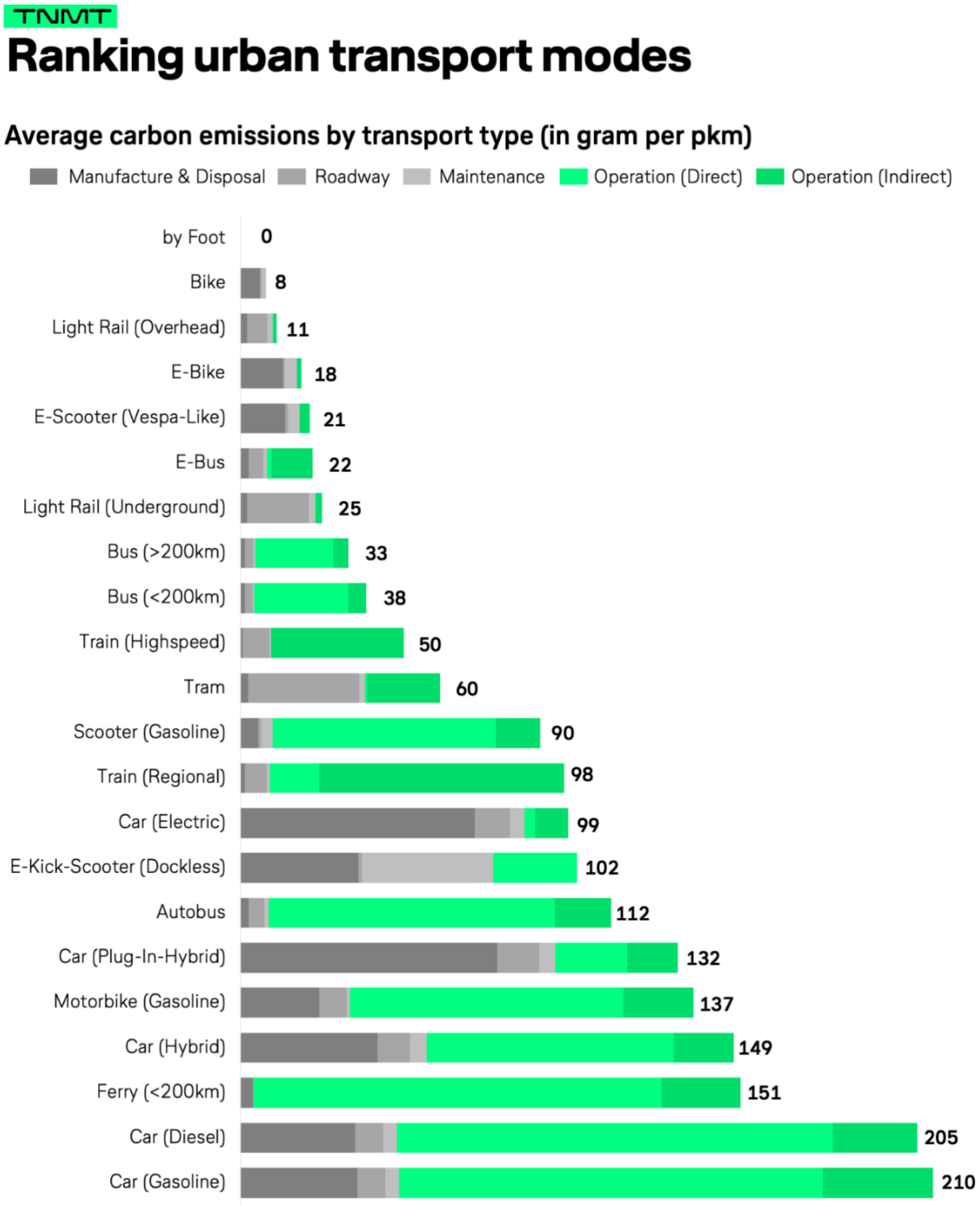

Figure 4: Average carbon emissions by transport mode broken down (TNMT, 2021)

2.1.4 Urban mobility in Zero-Emission Neighborhood (ZEN)

A neighbourhood is defined as a set of interconnected buildings with related infrastructure located inside a defined geographical area, according to the ZEN research centre. A zero-emission neighbourhood attempts to reduce its direct and indirect greenhouse gas (GHG) emissions to zero throughout the analysis period, in accordance with a set of goals for which life cycle modules, buildings, and infrastructure to include. To achieve the goal of zero-emission neighbourhood, the neighbourhood should promote sustainable transport patterns through the overall design of the neighbourhood and implementation of sustainable smart mobility systems both locally and regionally. This can be achieved through good spatial planning and logistics. Key Performance Indicators (KPIs) in the mobility category are Green mobility, Access to public transport and the city centre, Car ownership and Off-street parking. These KPIs will be assessed at the neighbourhood level and do not include transport within buildings such as lifts and escalators (Wiik *et al.*, 2021).

2.1.5 Urban mobility in 15-min city

The 15-minute approach, also known as 15- or 20-minute city or 15- or 20-minute neighbourhood in the literature, appears to be a reasonably common model for the spatial and functional organization of the neighbourhood, as well as the city at large (Pozoukidou *et al.*, 2021).

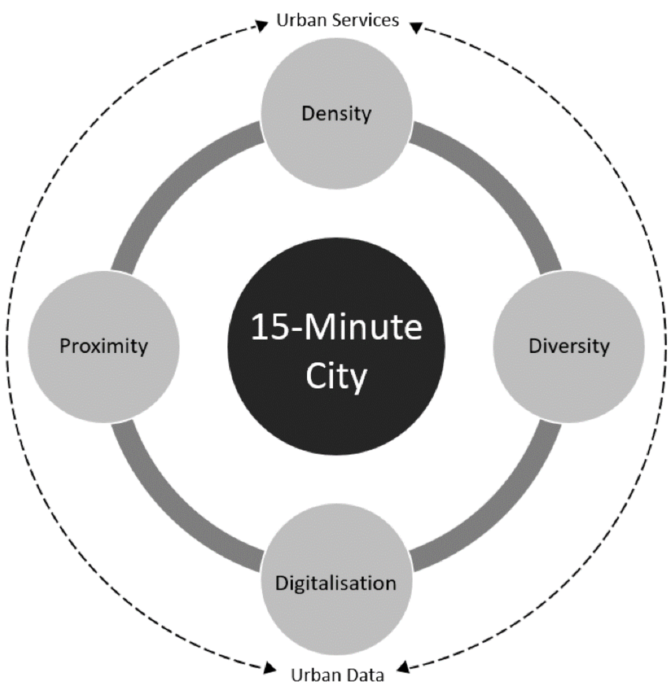

Figure 5: The 15-Minute City framework (Moreno et al., 2021)

The 15-Minute City is based on the idea of "chrono-urbanism," which states that the quality of urban life is inversely related to the amount of time spent travelling, particularly by car. This idea came from the original author, Carlos Moreno, who supports an urban environment in which residents may get all of their basic necessities within 15 minutes on foot or by bicycle. The capacity to walk or cycle to different areas of cities within the 15-minute time limit improves social wellbeing. Apart from walking, we believe that the time saved by not being stuck in traffic might be used to engage in other health-enhancing activities, both physical and mental. On this front, modern technologies have become more accessible and practical, thanks to the availability of wearables (including those that collect biodata) as well as urban sensors and data collection techniques that not only allow people to track their health but also provide large datasets that can be used to improve the area's liveability (Moreno *et al.*, 2021).

Pozoukidou *et al.* (2021), in their paper "15-Minute City: Decomposing the New Urban Planning Eutopia", explore this idea further by developing an evaluation framework based on the three main pillars of inclusion, safety and health. The intentional use of these terms offers an alternative evaluative context that goes beyond the platitude of the overall framework of urban resilience and sustainability and focuses on fundamental characteristics that define and enhance the concept of the neighbourhood as a "place" rather than "space" (Pozoukidou *et al.*, 2021).

2.1.6 Technologies that can support smart mobility

There are a number of enabling technologies that can help smart mobility adoption go smoothly. Some of these concepts can contribute to smart mobility services and infrastructures, starting with hardware-level data collection based on an IoT layer composed of multiple devices on multiple levels; then an aggregation layer with Big Data and the creation of datasets with massive amounts of data; and finally, AI-based processing of that data, which will allow trend prediction and decision support. All of the technology means, when integrated, allow individuals to get end-to-end services that increase mobility in smart cities (Paiva *et al.*, 2021).

Artificial intelligence may help businesses create new and more effective business models, as well as government agencies, provide more efficient, adaptable, and on-demand services. At the same time, there are several obstacles, particularly in terms of technology and personal data analysis. The widespread use of the Internet of Things, the development of high-capacity telecommunications networks, and access to transportation data are all necessary components for artificial intelligence to be used in mobility. The approach identifies potential uses such as automated transportation, intelligent traffic management, and infrastructure construction, operation, and maintenance (Rustad, 2021).

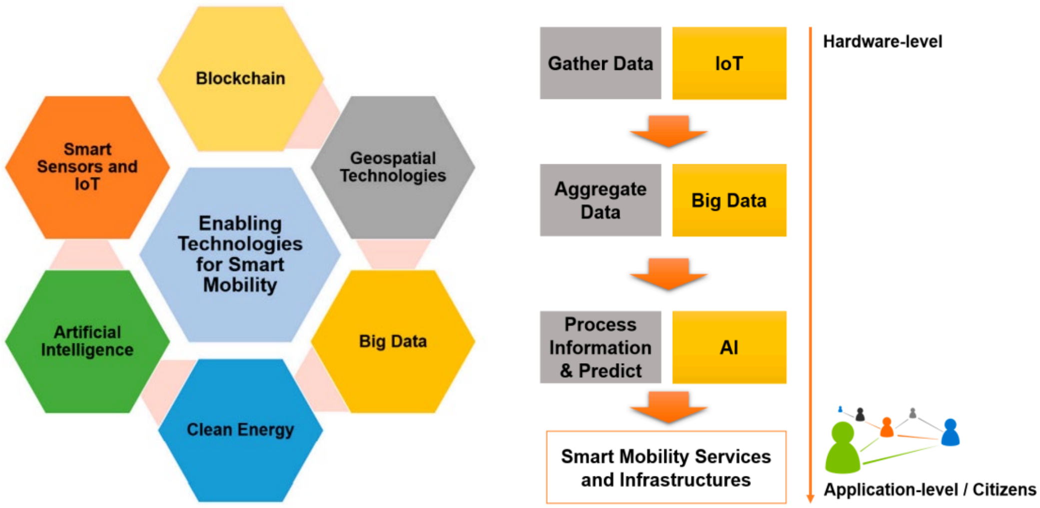

Figure 6: Contribution of some of the enabling technologies to smart mobility (Paiva et al., 2021)

2.1.6.1 Intelligent transportation system (ITS)

The term "intelligent transportation system" refers to projects that use information, communication, and sensor technology to improve vehicles and transportation infrastructure. ITS gives transportation system operators and road users real-time data, allowing them to make smarter decisions. The primary objectives of ITS are to improve safety, reduce emissions, and decrease traffic congestion. ITS stems from the idea that the use of technology may improve traffic flow while also boosting the safety and capacity of road networks (ITS Norway, 2020).

As a result of the significant growth in different travel needs, including vehicle traffic, public transit, freight, and even pedestrian traffic, congestion, accidents, and pollution concerns related to transportation are getting increasingly serious. ITSs, which may combine a wide range of technologies, including sensing, communication, information distribution, and traffic control, have been created to address these difficulties. Data collection, data analysis, and data/information transfer are three fundamental components for any ITS to execute its function(s) (Sumalee *et al.*, 2018).

2.1.6.2 GIS technologies in ITS

In practice, GIS technology may be based on users' actual needs, using GPS technology to translate important geographic information into an intuitive form and feed it back to users, allowing them to make proper decision and prevent lengthy user communication due to traffic congestion (Liu, 2018). Individual accessibility is improved through transportation networks. GIS in transportation (GIS-T) and intelligent transportation systems (ITS) are recent uses of GIS that emphasize on throughput (the quantity of system flow) rather than accessibility. Accessibility and throughput are linked but not identical. Accessibility measures that are rigorous, practical, and tractable are required for sensitive transportation planning (Miller *et al.*, 2000).

2.1.6.3 Mobility as a service (MaaS)

Mobility as a Service (MaaS) is a mobility distribution paradigm in which a service provider meets all of a customer's key transportation demands through a single interface. Similar to mobile phone price plans, services are grouped into a package (Figure 7). The goal is to consider the whole transportation industry as a collaborative, integrated eco-system that provides services that meet consumers' expectations. The lines between different modes of transportation are blurring or disappearing entirely. Transportation infrastructure, transportation services, transportation information, and payment services make the ecosystem (Hietanen, 2014).

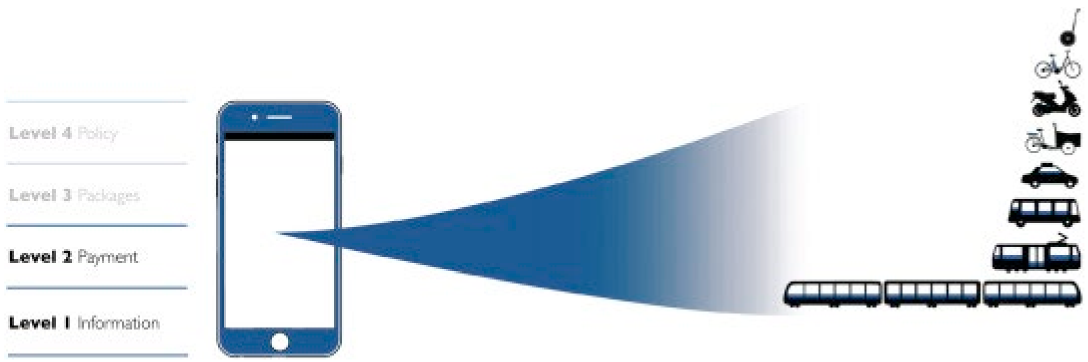

Figure 7: Principle visualisation of MaaS. (Smith et al., 2020)

Whim is one of the first fully functioning MaaS operators globally. It is a service and mobile application developed by Maas Global Ltd. The Whim app was first fully launched in Helsinki during November 2017. Birmingham in UK and Antwerp in Belgium followed in 2018. The MaaS service in Helsinki incorporates public transport, taxi, city bikes and car rental. It includes travel planning, routes, bookings, tickets, and payments. For a monthly charge, users can choose from a variety of plan options to match their specific needs, the most well-known of which is "Whim Urban," which provides limitless usage of public transportation and city bikes.

With extra payments, exclusive bargains for short taxi trips and automobile rental days are available for this subscription option.

Non-subscribers can choose between "Pay as You Go" and "Whim Unlimited," which includes unlimited usage of all mentioned transportation options (public transport, city bikes, taxi and rental cars). "Whim Weekend," which lies between "Whim Urban" and "Whim Unlimited," is the newest addition, giving unlimited automobile rental just on weekends (Ydersbond *et al.*, 2020).

2.1.6.4 Digital twin city

As an unavoidable trend of digital transformation, the digital twin assists cities in real-time remote monitoring and enables more effective decision-making. Digital twin cities rely heavily on data as a strategic resource. A data centre, particularly a city's super data centre, is responsible for managing the whole life cycle of all data in the digital twin city (Deng *et al.*, 2021). In terms of basic theories and cutting-edge technology, transportation infrastructure currently confronts several challenges. Intelligence is one of them, and it is a key development direction for industrial innovation. The digital twin is now an excellent candidate technology for promoting data and visual management of the whole life cycle of transportation infrastructure (Gao *et al.*, 2021). Al-Sehrawy *et al.* (2021) claim that digital twins can be used to manage the users' behaviours and also their usage patterns. They refer to several studies, including a study by Kırdar *et al.* (2020), aiming to encourage people to improve their travel habits by using technology through an integrated smart system design concept called Sustainability Aware Travel Service (SATS).

City planners may use simulations to evaluate future policies in a virtual setting, allowing them to modify transportation in a sustainable and efficient manner. The urban mobility ecology as a whole is becoming increasingly complicated. Planners and authorities may use the so-called digital twins of cities to shape and regulate urban transportation in a sustainable and effective manner. All road users and their interactions, as well as public transportation services, may be modelled and planned in this virtual environment. Before applying new measures in real life, they can be simulated and examined. Planners use "What-if-Scenarios" to help them make decisions. Traffic operators get a powerful tool for predicting, optimizing and controlling traffic and transportation by merging traffic models with real-time traffic data (Schmidt, 2021).

The city of Ålseund in Norway is one of the first communities to use smart city strategies in the development of urban management and public services. The Offshore Simulator Centre in Ålseund (Figure 8) is using its ship simulator's expertise and technology to undertake simulations related to urban development. A fire truck emergency service is an example. This can be visualized by using the simulator to collect a variety of big data. This leads to more effective decision-making, resulting in improved living experiences for citizens. Ålseund is on its path to being the first city in Norway to have a digital twin, thanks to this offshore simulation technology. Planners and policymakers can employ a digital twin, which is provided with data from the Internet of Things (IoT) on traffic, people's movements, electricity systems, urban lighting, and weather, to make more accurate and efficient decisions without digging up entire streets (DOGA, 2022).

Figure 8: Augment City from Offshore Simulator Centrein Ålesund (DOGA, 2022)

2.1.6.5 Citizen science

The participation of a growing proportion of the population in cities through citizen science or the new citizen observatories being constructed to gather more information on our environment may provide more data-gathering options (D'Hondt *et al.*, 2013) (Snik *et al.*, 2014). Citizen science is the active participation of the general public in scientific research operations, in which individuals actively contribute to science by their intellectual contributions, expertise, and tools and resources. Residents' observatories are communities where citizens gather to monitor and try to understand environmental issues, as well as to analyze, report, and comment on them. Involving individuals on the ground at a local level by building knowledge pools and acquiring and utilising their information would assist to foster an atmosphere of active involvement and promote a long-term movement that will lead to environmental governance empowerment (McGlade, 2009). Citizens can make use of the information to start making changes themselves or provide it to policymakers to make the changes (Nieuwenhuijsen, 2016).

2.2 Theoretical framework

In this section, different factors to evaluate smart urban mobility extracted from articles are presented and reviewed. A combination of all these factors that is more comprehensive is suggested to be used as an analysis framework for Nyhavna.

2.2.1 Factors used in the evaluation of smart urban mobility

Scientists have done many studies on smart city mobility systems, but there have not been many efforts to distinguish the smart mobility system assessment indicators. Furthermore, different scholars identify other indicators (Zapolskytė *et al.*, 2020).

Factors	Indicators
Smart infrastructure measures	Smart street lighting
	Smart street surfacing
	Electric vehicles charging stations, hydrogen stations
	Restricted traffic zones
	Special traffic lanes (for public or special transport)
Traffic management tools and services	Variable information and message signs
	Information, travel planning and online payment
	Vehicular communication systems
	Traffic light management system
Travel safety and accident reduction measures	Autonomous vehicles
	Automated control of safe travel for commercial vehicles
	Traffic monitoring systems
	Smart speed reduction
	Smart pedestrian and bicycle crossings
Pollution abatement measures	Emissions Testing and Mitigation
	Modern parking solutions
	Environmentally friendly vehicles
	Use of alternative fuels and renewable energy sources in PT
Motor travel and congestion reduction measures	Park and Ride system
	Carpooling
	Low-power electric vehicle sharing
	Bike sharing
	Car sharing

Table 4: Factors and indicators of smart urban mobility systems (Zapolskytė et al., 2020)

More than 50 indicators have been used to define various elements of the smart transportation system, with topics such as accessibility, service, safety, technological integration, and equity being among them. Here 30 of the most commonly utilized indicators are selected, which are given in the table below (Chen *et al.*, 2021).

Indicators	**Themes**
Public transport supply/service	Accessibility
Low-emission vehicles	Sustainability
Integrated and electronic ticketing system	Innovation
Cycling lane	Sustainability, Accessibility
Bike-sharing	Sustainability, Innovation
Car-sharing	Innovation, Accessibility
Mode choice	Accessibility
Modern parking solutions	Innovation
Traffic coordination/operation system	Innovation
Real time travel planner	Innovation
Travel time	Accessibility
Restricted/special traffic zones	Sustainability
Intelligent traffic light/Smart Street lighting	Innovation
Mobile phone apps	Innovation
Public transport demand	Accessibility
Variable message sign	Innovation
In-vehicle technologies: AVL, CCTV, detection, GPS	Innovation
Pedestrian zones	Sustainability, Accessibility
Road fatality rate	Sustainability
Private transport supply	Accessibility
Autonomous Vehicles	Innovation
Sustainable mobility plans/measures/investment	Sustainability
Electronic bus stop signs	Innovation
Electric charging devices	Sustainability
Mobility difficulties	Accessibility
Internet access/services	Innovation
Park and ride	Innovation
Air quality	Sustainability
Road transport energy consumption	Sustainability
Travel cost	Accessibility

Table 5: Most used indicators in reviewed articles (Chen et al., 2021)

2.2.2 The critique of evaluation factors

Zapolskytė *et al.* (2020) classified the indicators based on five factors of smart infrastructure measures, traffic management tools and services, travel safety and accident reduction measures, pollution abatement measures, and motor travel and congestion reduction measures. Chen *et al.* (2021) classified the indicators into three themes accessibility, sustainability, and innovation. The problem with this classification is that many of the indicators belong to two or three of these themes. Considering the climate and environmental goals of the Norwegian national transport plan (*National Transport Plan 2022–2033*, 2021), since sustainability is one of the main goals, I decided to keep sustainability as one main factor in developing a framework for Nyhavna analysis. I also used three factors of traffic management, travel safety, and smart infrastructure, as suggested by Zapolskytė *et al.* (2020), since these are directly related to mobility.

I merged pollution abatement measures into the sustainability factor so it will be more thorough. Accessibility indicators are merged in traffic management. Although innovation is a key to making mobility smarter, I decided to disperse innovative indicators among other related factors, which mostly deal with smart mobility infrastructure. Other indicators are enhancing travel safety or helping with travel management, and a separate factor for innovation appears to be unnecessary.

2.2.3 Suggested smart urban mobility framework

The final framework that is derived from the previously introduced factors to evaluate smart urban mobility is shown in table 6. The reasoning behind choosing this arrangement is as explained in the critique of the evaluation factor. The framework suggested to be used for Nyhavna smart urban mobility analysis in this thesis is classified based on four main factors of sustainability, traffic management, travel safety, and infrastructure.

Three main fields of energy consumption, access to clean energy, and emission control will be discussed to analyse sustainability in Nyhavna smart mobility.

Smart traffic management is investigating traffic flow management, parking management, and integration of public transportation modes.

Smart travel safety is discussing solutions to reduce road injury and fatality.

Lastly, smart infrastructure is evaluated by the logistics infrastructure, natural hazards prevention, and managing pollution caused by transportation activities.

This framework will be used as the basis for the analysis of smart urban mobility in Nyhavna. The same structure is used in giving recommendations in the last chapter.

Smart sustainable mobility	Is the Nyhavna proposed accessibility supporting the zero-emission goal?
	What are the smart solutions to reduce energy consumption regarding transportation?
	What are the smart solutions to reduce energy consumption in the transportation system?
	How to provide smart access to clean energy for transportation?
Smart traffic management	How smart is predicting the traffic flow?
	How smart is the parking management?
	How much are the public transportation services smart and integrated?
Smart travel safety	What are the smart solutions to reduce road fatality and injury rates?
Smart infrastructure	How smart is the transportation infrastructure in the prevention of natural hazards?
	How smart is the logistics?
	How is the case dealing with noise and dust caused by traffic?

Table 6: Smart urban mobility framework for evaluating Nyhavna By author

3 Methods

This chapter introduces the methodological approach that is employed to answer the questions of this research. A combination of methods is used, which are introduced in detail. Finally, the conceptual framework of the research is illustrated to organise the idea of the research.

3.1 Research scope and Methodological approach

The thesis is research-based, based on fieldwork combined with relevant theories.

Within the theory chapter, the characteristics of smart cities are defined, and a set of factors for efficient smart urban mobility are introduced in the form of a framework. The case study is analysed based on the framework, and finally, several measures are recommended in the last chapter. The details of the methods are elaborated further in this chapter.

While investigating the literature of the research and previous studies on the urban planner's role in smart urban mobility, I noticed that there is not much research done on the urban planner's role in smart cities in general and in the field of smart urban mobility specifically. Therefore, there is no documented valid proof that urban planners must be involved in the process of planning for smart urban mobility. In this thesis, I am questioning the need for doing more studies on if urban planners' participation in smart cities and in the field of smart urban mobility is necessary and how this cooperation can be beneficial for both sides. With the help of analysing the case study, it is expected that the findings of this research can verify/falsify the hypothesis of urban planners' positive role in planning for smart urban mobility.

It is possible to validate or falsify a theory by comparing the empirical data with the predicted findings derived from a theory and a case (Johansson, 2007). This research is not claiming that the grounded theory approach is adopted despite the fact that a case study is used to test a theory by analysing the data.

The grounded theory method clearly challenges the benefit of speculating at a high degree of abstraction and then doing empirical research to determine if the hypothesis holds up. It is far preferable to construct ideas based on actual investigation and then progressively build up broad theories from the evidence (Denscombe, 2017). The findings from one case is not enough to generalize the result and claim that the urban planners must be included in planning for smart urban mobility. Yet, the positive result of this research can claim the importance of testing the hypothesis further with other case studies to ground a theory.

The question of the research is:

- ***Should urban planners have a role in planning for smart urban mobility?***
- ***How can urban planners contribute to smart urban mobility?***

Sub-questions:

- ***How can urban planners employ smart urban mobility solutions?***
- ***How can urban planning prepare the ground to develop smart urban mobility in Nyhavna?***

The thesis applies several methods, including framework development, data collection methods, and case study.

3.2 Data collection

Different methods to collect data, including literature review, desktop research, and observation, are used.

3.2.1 Academic literature review

Building a research project on existing knowledge and tying it is the foundation of all academic research activity, regardless of the subject (Snyder, 2019). The Literature Review should include other people's work that gives a foundation and context for a study, whether the findings are used to support a case to extend something, or the researcher identified a problem and is conducting research to fix it (Candy, 2006). To select the articles for literature review, I used Oria, which is the NTNU university library and the google scholar search engine. The main keywords to find related articles were “Smart City”, “Smart Urban Mobility”, and “Smart Transportation”, and combining these concepts with urban planning in phrases like “Urban planners and smart cities”. Then I looked for “Urban Mobility” in the latest urban planning trends such as “ZEN”, “Low-carbon cities”, and “15-min city”. I added the studies on the latest technologies that are used in the urban mobility field to cover the smart mobility innovations. Finally, to build a framework for the thesis, I reviewed the literature that provides assessment indicators and factors for smart urban mobility. Unfortunately, there are a few studies done on this subject, and most of them are focused on technological aspects of smart urban mobility. Therefore, I extracted the urban planning-related indicators to build a framework specifically for this study.

3.2.2 Secondary data collection

It is possible to use data obtained previously by other researchers or for reasons other than studies, such as official statistics, administrative records, or other accounts held regularly by organizations, to answer some social research issues. Any form of original data may be used as secondary data if it is archived and made available. Researchers face a variety of particular problems when using secondary data. To begin, researchers must identify data sources that may be relevant to their study subject. Second, they must be able to access the required data. Third, it's critical to assess how well the data match the present research's quality needs as well as the methodological criteria of good scientific practice (Hox *et al.*, 2005).

Within this research, several types of secondary data were required to gain knowledge about the context of Nyhavna and its future developments. This data is collected from reports at the national and local levels published by governmental organisations such as the "ministry of transport" and "Trondheim municipality". Another secondary source of information was +CityxChange which is a smart city project cooperating with Trondheim municipality. Also, the related projects introduced by AtB mobility company that provides transportation services for Trøndelag are useful as examples of mobility initiatives in the same context as the case study.

3.2.3 Observation

A researcher can use observation to acquire data in a unique method. It is not based on what people claim to do or what they believe. It is a little more straightforward than that. Instead, it relies on direct eyewitness of events at firsthand. It's founded on the idea that, for certain purposes, it's preferable to just watch what happens (Denscombe, 2017). I started observing Nyhavna in different stages of the research. It helped to notice the important aspects of urban mobility that I missed during the first observation. Most of the analysis chapter is based on the development plans of Nyhavna, which are not observable currently. However, to have a clear perception of future developments, it is necessary to understand the current transportation network of Nyhavna and the current problems that need to be solved.

3.3 The conceptual framework of the research

A conceptual framework is designed to answer the questions of the research. The framework, as illustrated in the figure 9 clarifies the relationships between the input elements, the concept of the research, and the findings.

The suggested framework uses the literature review, the collected data from observation of the case, and the data provided by current studies and plans for the future of the case study as inputs of the research.

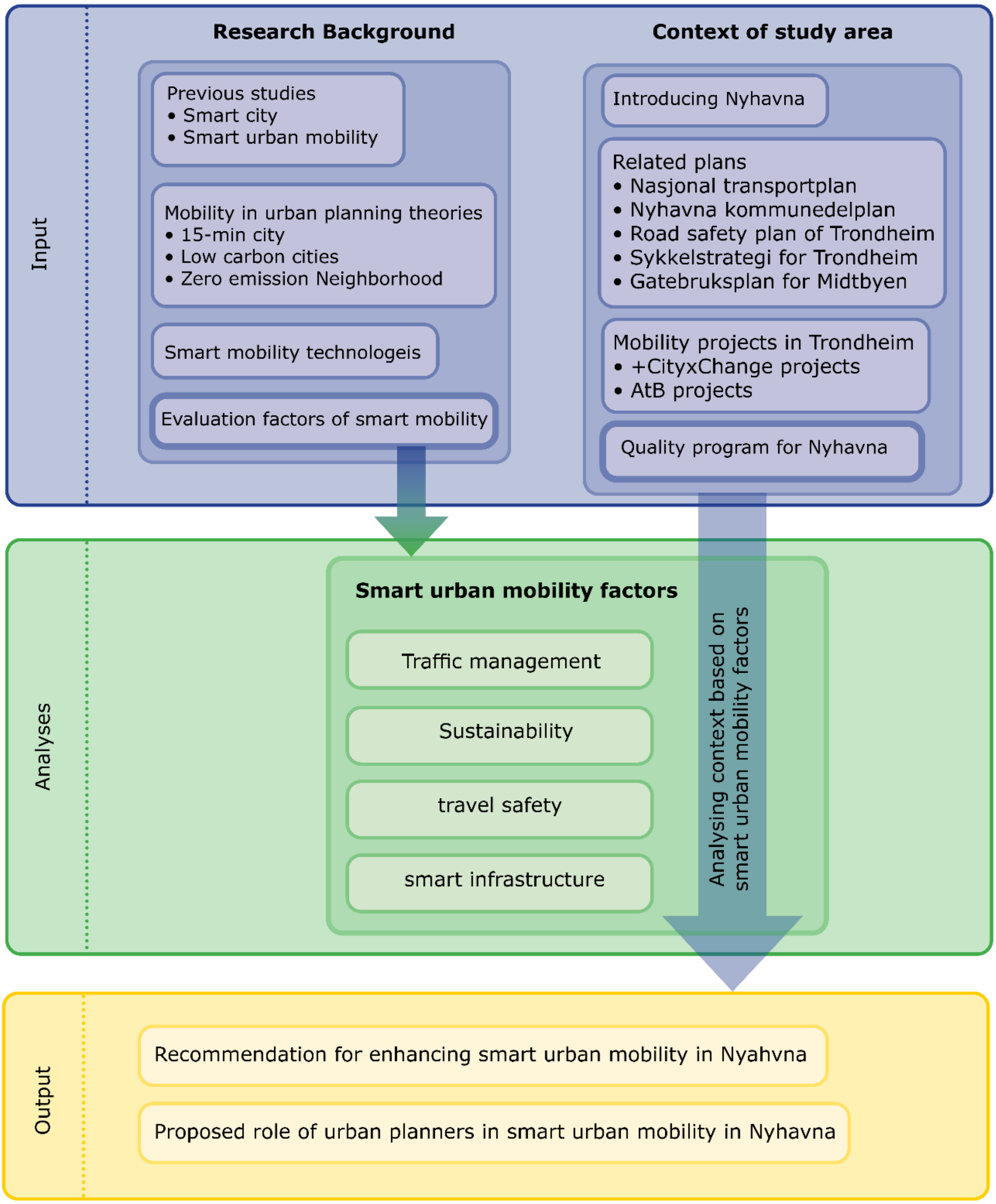

Figure 9: The conceptual framework. Source: Author

3.4 Case study method

The logic behind focusing efforts on one case rather than many is that there may be insights to be gained from looking at the individual case that has broader implications and, more importantly, that would not have been discovered using a research strategy that attempted to cover a large number of cases – a survey approach. The goal is to shed light on the general by examining the specific (Denscombe, 2017).

3.4.1 The case study of Nyhavna

When a researcher wishes to analyze a topic in-depth and give an explanation that can deal with the complexity and intricacy of real-life circumstances, the case study method works well (Denscombe, 2017). To investigate how urban planners' participation in planning for smart urban mobility can be important, I decided to choose a case study. Nyhavna harbour area, located in the north of Trondheim, is selected to be investigated within this research.

The reason behind selecting this area is the future potential of the Nyhavna. The area is planned to be developed as a new city centre along with residential, business, social, and cultural functions. The district is planned to have a high degree of public transport accessibility, low car traffic, and good pedestrian and bicycle connections, with good accessibility (Team AGRAFF, 2020). Based on the above-mentioned goals for future developments, Nyhavna is a fitting case to be investigated. Building smart urban mobility requires expensive infrastructure. Mobility infrastructures are long-term facilities and constructions. Therefore, a comprehensive study and planning in advance of starting the construction are needed.

In addition, the Nyhavna case study can contribute to answering the research question of "*How can urban planning prepare the ground to develop smart urban mobility in Nyhavna?*" as an example of how can, urban planners have role in planning for smart urban mobility.

The required data for case study analysis are mainly the secondary data that is introduced earlier in this chapter and will be explained later in the context of the research. The data will be analysed in the case study analysis. Additionally, the data gathered during observation will be used for analysing the case study from an urban planning perspective.

3.4.2 SWOT analysis

SWOT analysis is a method for objectively and precisely analyzing and studying the status of a unit. This method was developed by management professor Weihrich at the University of San Francisco in the early 1980s. Strength, Weakness, Opportunity, and Threat are the four letters that make up SWOT. SWOT is separated into two parts: the first is SW, which is mostly used to examine internal circumstances, and the second is OT, which is primarily used to study external situations. We can use this strategy to identify those variables that are to our benefit and worth promoting, as well as those that are undesirable. We may also identify problems, identify remedies, and determine future development paths (Zhang, 2012). I used this method to analyse the study area. Since the developments of Nyhavna are the main focus in this research, the proposed strategies and measures from the developments plans of Nyhavna are also noted in the analysis in addition to the current state of Nyhavna. I tried to classify the identified characteristics based on the proposed framework in 2.2.3. I used SWOT analysis to analyse smart urban mobility in Nyhavna from urban planning perspective.

3.5 Methodological challenges and Limitations

There have been several challenges and limitations in different stages of this research, including the data collection and literature stage and case study stage.

3.5.1 Literature review limitations

Unfortunately, there is not much literature available about smart urban mobility in urban planning. Therefore, I had to look for different related fields separately and find the links to connect each part to each other. Each part might not be directly related to the urban planner's role in planning for smart urban mobility, but all the pieces of knowledge introduced in the literature review are required to provide a comprehensive understanding of the research.

3.5.2 Developing framework limitation

The first challenge in developing a framework for the research was finding similar research. There are a few pieces of research done that I combined to make the current framework. Yet, the current framework is limited to the current research. The framework is tried to be adapted to the case study. To give an example, de-icing and heating infrastructure in urban mobility is a smart mobility factor in Nyhavna and in cold zone countries in general. Accordingly, it is not possible to have a comprehensive checklist to evaluate smart urban mobility that can be applied universally. Apart from that, the factors to be considered in such a framework are based on the limited knowledge of a researcher in their relevant field of speciality, while urban planning is a multidisciplinary field of study which requires considering urban mobility from different aspects. Therefore, the framework needs to be updated frequently, and adaptation to the local study area might be necessary.

3.5.3 Case study limitations

Currently, Nyhavna is a port area with few a few urban activities (figure 10) which is planned to be developed. It is difficult to analyse the future state of urban mobility before the developments. Gathering data is very challenging and mostly dependent on municipal plans. Data gathering through observation is very limited. Researchers have to rely on imagining the future plan in the current state to be able to analyse it. Predicting the future state of a study is not giving an accurate image of the future. Yet, smart initiatives and technologies that can be used as predicting tools, such as digital twin, are helpful.

Figure 10: Current state of Nyhavna. Source: Author

3.5.4 Language barriers

Since most of the secondary data that is used in this research are written in Norwegian, translating the documents has been challenging and very time-consuming. Due to the uncertainty in translating the phrases that do not have an exact equivalent English translation, I included the Norwegian words along with my own English interpretation.

4 Context of the case study

In this chapter, the study area is introduced along with its history. Then current studies and plans as well as current projects in Trondheim, and more specifically in Nyhavna, are explained.

4.1 Study area

Nyhavna is a port area in Trondheim which is bounded by Ladehammeren from the north and Nedre Elvehavn from the south, Nidelva river from the west, and Lademoen from the east. Nyhavna's location in Trondheim and Norway is illustrated in figure 11.

Trondheim Port Authority operates and manages the port area (figure 12) on behalf of the municipality, which is the owner of this area. Trondheim Port Authority facilitate infrastructure for maritime transport like cargo shipping, cruise tourism, passenger traffic, and leisure boats. Trondheim Port Authority is self-financed and does not receive any public funding. For that reason, the port must maintain acceptable profitability and a sustainable economy in order to meet the future requirements of maintenance and investment (Trondheim Port Authority, 2022).

Figure 11: Nyhavna location in Trondheim and in Norway, map source: (kart.finn.no, 2022) edited by author

Figure 12: An above view of Nyhavna (TrondheimHavn, 2019)

The central industrial and port districts of Nyhavna are being transformed for urban purposes as part of a large development project. This creates a challenging restructuring opportunity for many of the current businesses in Nyhavna. This might have a significant impact on current operations. At the same time, Nyhavna's upcoming development offers exciting opportunities for new stakeholders and businesses (Trondheim Port Authority, 2022). The proposed plans for Nyhavna development are not approved yet. Figure 18 illustrates a proposed view of what Nyhavna might look like in the future. It is a proposed design by Mad Arkitekter (2019).

Figure 13: A proposed overview of future development (Mad Arkitekter, 2019)

4.2 History of Nyhavna

Elvehavna was a prerequisite for the later flourishing trading business with exports of lumber, fish and copper in the 17th century. The Tiller landslide in 1816, however, caused poor conditions for shipping in the Nidelva, and after discussions, a new pier and canal were built in the 1860s, and the areas at Brattøra and Ilsvika were taken into use. In the 1880s, the Meråker line got its terminus at Brattøra with a connection to the Røros line. The railway streamlined the transport of goods between the port and the city's surrounding area. Eventually, there was a need to expand the harbour, and at the beginning of the 20th century, the east side of the Nidelva was taken into use, and Nyhavna was established. Nyhavna, as we know the area today, was built according to the River Plan in 1937 (Kildal *et al.*, 2020).

Figure 14: Pier II under development in 1949 (Trondheim Havn, 2022)

The river was changed, and afterwards, new docks at Nedre Elvehavn were established as an extension of the Nidelva. Pir I and Pir II were established in the extension of the west side of the river. Several pools were established with the development of the port area. Pir II was extended to its current length in 1949-52. You can see Pier II under development in figure 14. During World War II, the Germans cordoned off the eastern parts of the harbour and built the submarine bunkers Dora 1 and Dora 1I. The marine operations and the unique cultural monuments from World War II still characterise the physical surroundings of Nyhavna (figure 15). In the post-war period, Nyhavna was used for several different industrial and commercial purposes. Larger companies such as Dillner & co Trevareforretning and Isisdor Nilsen’s mechanical workshop had their operations here. The large white brick building of EC Dahl’s brewery long dominated the landscape along Strandveien (Kildal *et al.*, 2020).

Figure 15: Buildings build during World War II, Source: Author

4.3 Related development plans and strategic plans on a national to local scale

In this section, the national transport plan of Norway for 2022-2033, the Nyhavna municipal sub-plan, and the quality program for Nyhavna are introduced, and the related research and mobility projects done by +CityxChange (Positive City ExChange) and AtB in the transportation field are mentioned.

4.3.1 Norway national transportation plan (Nasjonal transportplan 2022–2033)

In the National Transport Plan 2022–2033, the government has emphasised developing an efficient transport system that provides everyone freedom and opportunities, increases the quality of life, contributes to value creation, protects and saves lives, and helps to improve health, the environment and the climate (*National Transport Plan 2022–2033*, 2021). The policy objectives stated by the national transport plan are presented in figure 16.

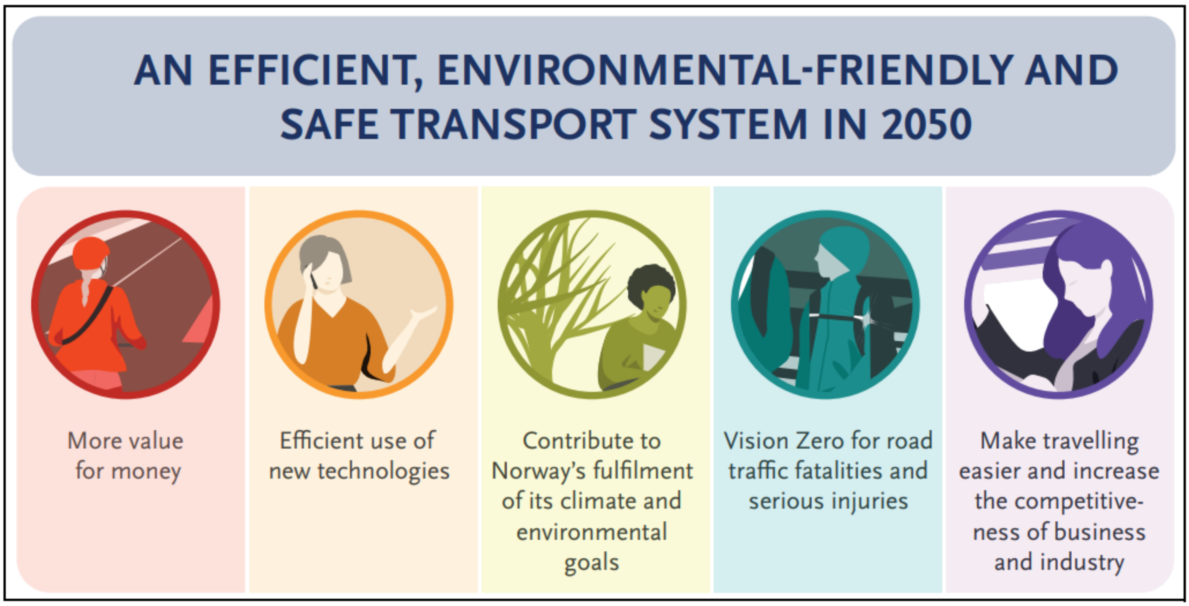

Figure 16: The policy objectives for the transport sector (National Transport Plan 2022–2033, 2021)

4.3.2 Nyhavna kommunedelplan (Municipal sub-plan)

The municipal sub-plan for Nyhavna was approved by the city council on 28 April 2016. This is the first phase in a transformation of a central district. The purpose of the plan is to facilitate an urban structure with urban settlement and diverse land use, a well-connected bike and pedestrian-friendly street network, environmentally friendly transport solutions, and a coherent green structure with pleasant living areas. The plan booklet was published in 2011, but it was updated several times after. The updates are available on the Trondheim municipality webpage (Trondheim Kommune, 2011).

4.3.3 Trondheim kommune plans by mobility and transport unit

4.3.3.1 Road safety plan of Trondheim (Kommunedelplan for trafikksikkerhet 2020-2024):

Based on the Road safety plan of Trondheim (2019), Trondheim municipality has a goal of zero growth in passenger car traffic, which means that other road user groups must increase. Within this report, the municipal director has screened and prioritised issues where measures have the greatest probable traffic safety effect.

In addition to physical measures, attitude-creating, organisational, technological, and operational measures have been proposed by this report.

In addition to Trondheim municipality, there are several agencies and authorities that work with traffic safety in the municipality:

- The environmental package (Miljøpakken)
- The Norwegian Public Roads Administration (Statens vegvesen)
- Trøndelag County Municipality (Fylkeskommunen) has a traffic safety committee, which is an advisory and coordinating body for traffic safety work.
- Safe Traffic (Trygg trafikk)

The most important administrative units involved in road safety work are:

- **The City Planning Office (Byplankontoret)**
- **Kommunalteknikk** which manages municipal infrastructure.
- **The environmental package unit (Miljøpakkeenheten)**
- **The ownership unit (Eierskapsenheten)** which manages and develops municipal land and collaborates with private or public developers through development agreements.
- **Trondheim property (Trondheim eiendom)** has an important role in ensuring traffic safety within the schools' area and adjacent areas.
- **The environmental unit (Miljøenheten)** ensures that national guidelines for noise, dust and health are met through public planning.
- **Trondheim Bydrift** owns, operates and maintains the municipal road network as well as parts of the county and state roads.

- **Trondheim parking**: Parking regulation and monitoring can contribute to better traffic safety.

4.3.3.2 Cycling strategy for Trondheim (Sykkelstrategi for Trondheim 2014-2025)

The City Council adopts the proposal for a cycling strategy for Trondheim 2014–25 (Trondheim kommune *et al.*, 2014). Some of the guidelines are as follows:

- Trondheim is to be Norway's best cycling city. The bicycle share will increase, the risk of accidents should be reduced, and Trondheim will have a coherent main network for cyclists.
- The goals shall be achieved through a combination of several instruments:
  - Build good physical cycling facilities
  - Establish good operating and maintenance standards for the bicycle facilities
  - Conduct effective communication and training among cyclists and others
  - Develop a bicycle-friendly land use pattern
  - Make it easier to get a bicycle on public transport
- Safe intersections are being built.
- Good and safe parking facilities are being arranged with more bicycle parking spaces near public transport stops.

4.3.3.3 Street-use plan for city center (Gatebruksplan for Midtbyen mot 2030 og 2050)

Although this is the street use plan (City Planning Office in Trondheim municipality, 2020) for the city centre, it gives suggestions regarding connection to the Nyhavna area:

Towards 2050 it is recommended:

- Several bridge connections, especially towards densification areas such as Nyhavna, Reina and Jarlheimssletta
- Consider extending and expanding the tram route towards Brattøra / Nyhavna and St. Olavs hospital / Gløshaugen

Towards 2030 it is recommended:

- Establish several mobility houses at a key point outside Midtbyen, including Nyhavna.
- Accelerate the assessment of extending and expanding the tram route towards Brattøra / Nyhavna and St. Olavs Hospital / Gløshaugen to 2030.

4.4 Quality program for Nyhavna

The quality program for Nyhavna was approved by the City Council on 16 June 2016. The plan was later submitted for public scrutiny of the presidency (Formannskapet) in 2020 and was not yet approved (Trondheim Kommune, 2020). The main purpose of this program is to plan the transformation of Nyhavna from an industrial district to a city centre. Quality programs for Nyhavna shall form the basis for all further plans for Nyhavna. The new development will be arranged for more people to be able to settle close to the city centre, close to cruise and speedboat quays, railway and metro bus stops and the entire region's public transport hub, Trondheim Central Station. The most space-consuming and noisy industries will move out, but the development will at the same time pave the way for many new workplace-intensive industries. If more people live and work in Nyhavna, it will strengthen Midtbyen as a city centre and provide good opportunities for more people to choose walking, cycling and public transport as a means of transport in everyday life (Kildal *et al.*, 2020).

This document constitutes the base for Nyhavna analysis. Although this document is not approved, it is planned based on the approved municipality sub-plan. However, since the municipality sub-plan does not provide the details on the developments, the quality program for Nyhavna appears to be more helpful. It provides a more clear vision of the future changes.

4.4.1.1 Access and mobility in the quality program for Nyhavna

As it is stated in the quality program for Nyhavna, The urban environment at Nyhavna will be adapted for everyday life with minimal passenger car use. Mixed land use with local services, good public transport coverage and a short distance to other downtown areas minimises the need to use your own car, both for those who live, visit and work in Nyhavna. Accessibility for passenger car drivers is subordinate to the accessibility and needs of public transport, walking and cycling, and other desired urban qualities are prioritised over the needs of car drivers. There is a dense network of connections for street users, and connections are being upgraded so that Nyhavna is integrated into the rest of the city. Choosing public transport, cycling, and walking should be more attractive and easier than choosing the car, while all streets provide access to necessary traffic (Kildal *et al.*, 2020).

The transportation network based on both the municipality sub-plan and the quality program for Nyhavna is proposed in figure 17.

Figure 17: Proposed transportation network of Nyhavna (Kildal et al., 2020)

4.5 Related mobility projects in Trondheim

4.5.1 +CityxChange projects in the smart mobility field

+CityxChange (Positive City ExChange) will develop solutions for Positive Energy Blocks, which will lead to Positive Energy Districts and Cities through (i) decision support tools, urban planning support, city strategy development, and transforming urban environments, which will allow all stakeholders in the community to make informed decisions, and (ii) an approach to creating a Positive Energy Block through energy reduction and efficiency measures, local renewables, local storage, flexibility, and peer-to-peer energy trading (iii) Bottom-up citizen involvement and top-down community engagement to transform people's perspectives and build, inform, include, educate, and promote behavioural change (Positive City ExChange, 2019).

EMaaS project integrating seamless e-mobility within the PEB (Positive Energy Block) is one of the projects that +CityxChange is working on currently.

The +CityxChange Seamless eMobility Platform and frontend is a Mobility-as-a-Service (MaaS) solution that allows users to go from point A to point B using public transportation and personal transportation through shared EVs and/or E-Bikes or a combination of several/all modes. This new innovative idea will help to expand the number of electric vehicles in cities across Europe. A large number of EVs will require charging, but they may also participate in the DPEB by returning energy that is not expected to be used, therefore temporarily lowering their range. The energy recovered from EVs can be utilized to supplement the DPEB's energy requirements. The concept is known as Vehicle to Grid (V2G) or Vehicle to Building (V2B) (Limerick team, 2020).

Mobee is a Mobility as a Service (MaaS) application that enables citizens to travel easier in Trondheim and Trøndelag. This application is powered by +CityxChange.

4.5.2 AtB as a mobility company in Trondheim:

The mobility company administrates the public transport in Trøndelag. As a mobility company, AtB will facilitate easy and seamless travel adapted to different needs and travel patterns. The public transport will be developed and presented together with cycling, walking, and sharing services. The goal is for travellers to get easily from A to B without using their own car. AtB is registered as a limited company and is fully owned by Trøndelag County Authority. AtBeta refers to all of AtB's innovative mobility initiatives that they are working on with its travellers and partners. Transparency, participation, and wide engagement are required for future mobility services. As a result, AtB encourages residents who care about Trndelag's mobility services to join AtBeta in developing initiatives that will lead to ready-made, integrated mobility services. Everyone's participation is important, whether someone is a regular traveller, a student, a technician, a software developer, or just a creative thinker (AtBeta, 2021).

The related projects of AtBeta are as follows:

- 67plus

  The service can be pre-booked via the app or by calling 02867 no later than 1 hour before departure. The itinerary is scheduled according to the bookings made. The minibus is adapted for a walker and wheelchair, and travellers can bring a companion on board. 67pluss applies in the areas nidarvoll, fossegrenda, Risvollan, Stubban, Steinan, Voll, Nardo, Moholt, Tempe, parts of Berg, Tyholt, Rosenborg, Bromstad, Valentinlyst, Persaunet, Strindheim and St. Olav's Hospital. The following scope for 67pluss is to become a part of AtB’s mobility offering (AtBeta, 2022).

- Europe's first self-driving bus to order

The self-driving buses are tested in Øya in Trondheim (figure 18). The pilot project is done to give insight into how travellers and the surroundings have used and dealt with the service and technology. The bus was following a map that was built up using sensors that measure and scan the surroundings. The bus had fixed stops but did not follow a timetable. The journey was booked via the app, and the bus calculated the fastest way from A to B. Self-driving bus is a collaboration between Trondheim municipality, Miljøpakken, Applied Autonomy, Vy and AtB. The pilot period on Øya in Trondheim has been completed, and the project is under evaluation. In the next stage, the project is going to be tested elsewhere in Trøndelag.

Figure 18:Europe's first self-driving bus on order in Trondheim (AtBeta, 2022)

- SykkelSafe

Safe bike parking will make it easier to use bicycles and e-bikes as means of transport to work and school or in combination with buses or trains for longer journeys. SykkelSafe has a capacity of 10 bikes and is open 24/7. The service is managed via the app, and the box can be reserved up to one hour before use. SykkelSafe is supplied by SafeBikely, and the pilot project is carried out in collaboration with Steinkjer municipality. It is a pilot project at Steinkjer station currently (AtBeta, 2022).

The Bikely application, which provides a booking service for SykkelSafe, shows 14 available parking stations with 105 parking spaces. There is no SykkelSafe in Nyhavna or around it. A SykkelSafe parking space is illustrated in figure 19.

Figure 19: SykkelSafe, Safe bike parking (AtBeta, 2022)

5 Case study and analysis

In this chapter, smart mobility in Nyhavna's future plans is discussed, and urban planners' role in the related field is investigated. The measures and the proposed solutions by current programs overlap when classified based on different factors of the framework. This happens since mobility problems are highly influenced by each other. For instance, traffic management might lead to a more sustainable and safer transportation system. Thus, they are interrelated and classifying them is almost impossible. Therefore, I analysed Nyhavna mobility based on the smart urban mobility framework suggested in the theory chapter. I ordinated different measures based on how they influence the four main factors of sustainability, traffic management, travel safety, and infrastructure.

This chapter is the second phase of the conceptual framework, as seen in figure 20.

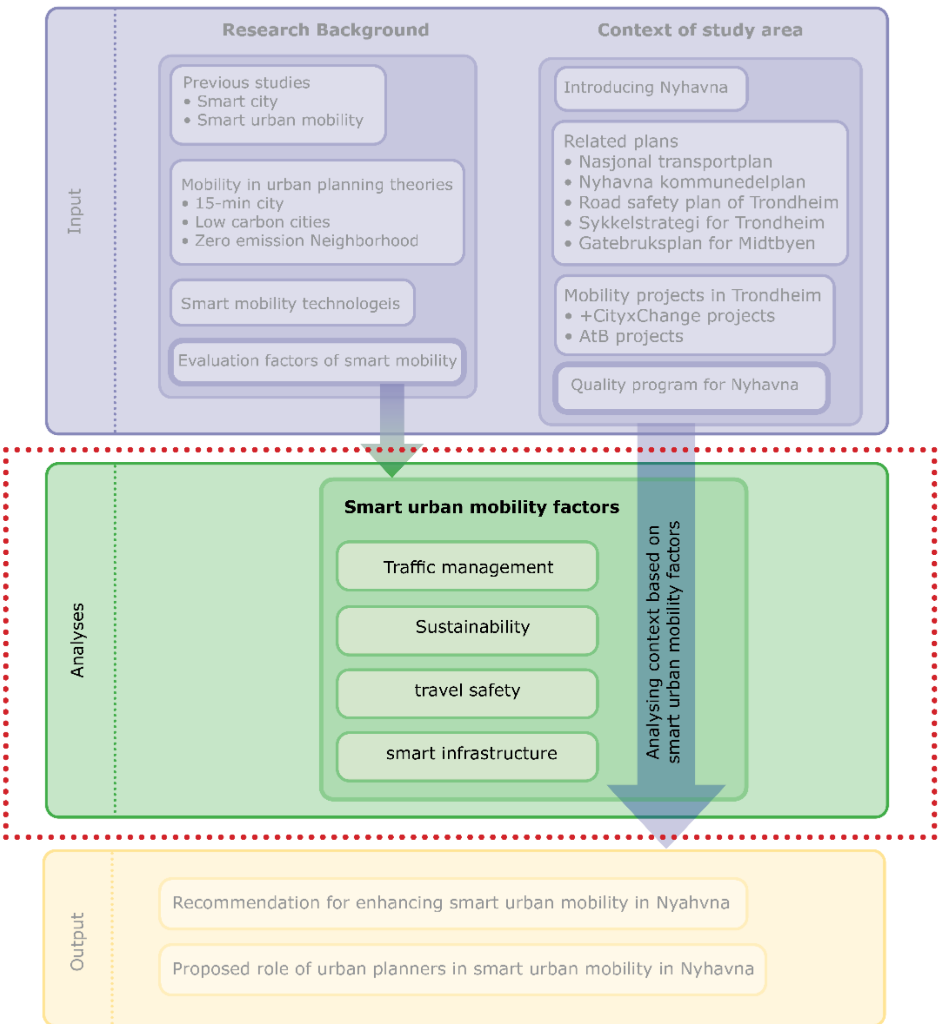

Figure 20: Analysis phase of the conceptual framework, Source: Author

5.1 Smart, sustainable mobility in Nyhavna

Sustainability has been mentioned in the literature review as a factor of smart mobility. Smart, sustainable mobility in Nyhavna is questioned about zero-emission strategies, energy consumption, and access to clean energy.

5.1.1 Is the Nyhavna proposed accessibility network supporting the zero-emission goal?

There are different aspects to controlling GHG emission in transportation, including promoting using low emission vehicles and optimising traffic to reduce travel time and delay times of the vehicles. Reducing travel time contributes to reaching zero-emission goals.

The quality program of Nyhavna claims all energy consumption and greenhouse gas emissions will be measured at the project and system level, documented, and followed up, from the early stages of planning to the final stages of the project and further in the operational phase, so that Nyhavna in practice becomes the zero-emission area. Although, it is not apparent how this method will be implemented in each stage and leads to decreasing GHG emissions.

Nyhavna will be developed as a ZEN area. For a zero-emission neighbourhood, the system boundary is raised from building level to neighbourhood level. An important prerequisite for area development is that Nyhavna should not lead to increased energy needs, power needs or greenhouse gas emissions at the city level. This means that buildings and the energy system at Nyhavna must interact with surrounding areas and the energy system. This requires a large degree of planning (Kildal *et al.*, 2020). Since the transportation network is integrated, it is not possible to distinguish between Nyhavna travels and the travels with their starting point or destination out of Nyhavna. Yet, the impact of future Nyhavna developments on the GHG emissions caused by transportation on the city scale is not clear.

From an urban planning perspective, the direct role of citizens in reducing GHG emissions is not considered. It is not mentioned how citizens are involved in this process. Since citizens' choices of transportation modes, types of vehicles they use, the parking area they use, etc., are affecting GHG emissions, their awareness and decisions are very constructive.

Nyhavna quality program (Kildal *et al.*, 2020) is planning for port activities as well. The port area will be built with a requirement for a zero-emission facility and sea-based transport, which can contribute to achieving this goal. The work of establishing a zero-emission port should be seen in connection with the future energy system at Nyhavna and will be an important part of the solution for fulfilling the decision on Nyhavna as a zero-emission district. Yet, no details are provided on the requirements and infrastructures of a zero-emission port that I could find. Trondheim port and SINTEF have been cooperating on a number of projects related to mobility, shipping, energy and infrastructure. The Trondheim fjord was established as the world's first test area for autonomous vessels in 2017 – on the initiative of SINTEF, NTNU, MARINTEK, the Norwegian Coastal Administration, Kongsberg Seatex, Maritime Robotics and Trondheim port (Trondheim Havn, 2020). The result of these initiatives is beyond the scope of this research. However, being familiar with the urban infrastructure needed for these developments is helpful.

5.1.2 What are the smart solutions to reduce energy consumption in the transportation system in the Nyhavna quality plan?

The quality program for Nyhavna claims that good accessibility for cyclists and pedestrians will be provided. A high-speed bicycle route for bicycles is planned along the railway track from Leangen to Brattøra to ensure efficient access from surrounding districts to the centre for cyclists. Besides, Nyhavna will have an urban structure with a dense network of pedestrians. The quality program suggests that cycling and walking must be given priority at traffic lights. This will reduce the energy consumed by vehicles for transportation purposes to a great extent.

However, Nyhavna is planned to be an attraction on the city scale, and many visitors need easy access by bike or on foot from the whole city. The importance of connecting Nyhavna to the city centre and the rest of the city has been stated several times in the Nyhavna quality program and street use plan for the city centre between 2030 and 2050. Yet, the accessibility of the pedestrian and cycling network and its connection to the city are not clearly demonstrated.

The quality program of Nyhavna claims that the railway, Riksvei 706, and Jarleveien are physical barriers that contribute to Nyhavna today being inaccessible to pedestrians and cyclists. Strandveien will be closed for traffic to Østersundsgate and will be an important connection for pedestrians and cyclists. Other important access points are the underpass by the railway (figure 21) and the harbour promenade along the Nidelva. More connections to Lilleby and Lade are essential for the districts to be well connected, and more crossings over Jarleveien should be established. Highway 706, with heavy traffic, has few crossing points for pedestrians and cyclists and forms a major barrier between Solsiden and Nyhavna (Kildal *et al.*, 2020).

Figure 21: Railway underpass as a connection to Nyhavna. Source: Author

Easy access to public transportation will contribute to lower energy consumption as well.

Metro bus stops are arranged so that Nyhavna residents have no more than 400 meters to the bus stops. The proposed location is at the intersection Maskinistgata / Kobbesgate and at the intersection Strandveien- / Stiklestadveien, close to important destination points in the district such as business, services, entertainment, train station, workplaces and public services (Kildal *et al.*, 2020). The access to the bus stations for residents is mainly a walking distance from their housing, workplace, and parking areas, including the mobility house.

A distance of 400 meters (approximately 5 minutes walking) is a commonly accepted distance to the nearest bus stations (Daniels *et al.*, 2013) (Mohamad *et al.*, 2021).

From an urban planning perspective, it is important to know that the actual walking distance is different from the perceived walking distance. When given a choice, pedestrians have been seen to prefer routes that are faster, safer, more comfortable, attractive, or beautiful (Sevtsuk *et al.*, 2022). The more a walking path is attractive, safe, and connected, the more pleasant the journey to the bus stop is. Consequently, people are willing to walk more than 400 m if they find the walking pathways enjoyable and less than 400 m if unpleasant.

Also, the walking travel times between bus stations that are estimated by public transport service providers are usually choosing the shortest route and estimating the required time for young people regardless of the user limitations and disabilities.

5.1.3 How is Nyhavna going to provide smart access to clean energy for transportation?

The quality program claims that by mapping the energy and power needs in the area, one can ensure a comprehensive design and layout of an energy system adapted to Nyhavna as a zero-emission area. There is a need to map the potential for energy production from the sea as part of the overall energy system as well (Kildal *et al.*, 2020).

District parking garages can be a central part of the energy system at Nyhavna, especially when it comes to the electrical energy supply. Future solutions where the car batteries in parked cars are included as part of the energy system can contribute to storage and two-way exchange of electrical energy, power equalisation and flexibility in the power market. Co-location between a mobility house and an energy centre and main transformer(s) for the area may make sense but must be studied in more detail as part of a comprehensive plan and design of an overall energy system (Kildal *et al.*, 2020).

It appears that the required clean energy for transportation in Nyhavna is going to be a part of a comprehensive energy system. The main parking area is planned to be the mobility house, and charging stations for electric cars, E-bikes, E-scooters, and other electric vehicles are suggested to be available in the mobility house.

From an urban planning perspective; integrating parking and charging station is an economical solution in terms of providing infrastructure. A significant benefit of leaving the vehicles to be charged in the mobility house would be less car traffic inside the neighbourhood. It might encourage residents to walk from the mobility house to their housing units. However, there is no certainty that people are interested in walking this distance in unpleasant weather conditions while carrying heavy bags and other physically disabling situations.

5.2 Smart traffic management in Nyhavna

The mobility qualities of a smart city include intelligent traffic planning, public transportation efficiency, and increased connectivity for all road users in a city. Public transportation networks that are efficient and well-managed are critical in the age of smart cities (Thiranjaya *et al.*, 2018). In this sub-chapter, I will question the traffic flow prediction, parking management, and level of integration in the public transportation network.

5.2.1 How smart is predicting the traffic flow in Nyhavna?

Because of the rapid advancements in machine learning and the availability of new data sources, it is now possible to assess and predict traffic patterns in smart cities with greater accuracy than ever before. This could aid in the optimisation of transportation service design and management in a future automated city (Nagy *et al.*, 2018).

The future programs for developing Nyhavna have not mentioned any specific plans for smart traffic management and how to control it by predicting the traffic. It is a challenge to predict the future traffic for Nyhavna since the development has not started yet. The suggested new streets and bridges both inside Nyhavna and accessibilities to outside Nyhavna are not built yet. Although it makes traffic planning very difficult, considering the requirements to create a smart traffic management system in advance would be beneficial. For a better understanding of the current state, the smart traffic management system that is used in Trondheim should be investigated, which requires further research.

Currently, AtB, as the mobility company managing public transportation in Trøndelag, will plan the bus routes and timetable and provides the information for citizens enabling them to plan their travels. Providing more accurate predictions makes it more trusting for citizens and encourages them to use public transportation services.

One advantage of accurate traffic flow prediction is to prevent heavy traffic jams and the noise and air pollution caused by that.

It is a challenge to handle noise from port operations and heavy traffic to and from Transittkaia responsibly. This applies in particular to Transittgata. Any health risks and environmental issues as a consequence of GHG emissions caused by delivering building materials by boat must also be considered (Kildal *et al.*, 2020).

Smart traffic prediction is assumed to be used for car traffic mainly. The quality program for Nyhavna (2020) has mentioned giving priority to pedestrians and cyclists at traffic lights. Smart traffic lights can be planned to recognise the priority of pedestrians, cyclists, or scooter riders.

Pedestrian route choice estimation, which requires a variety of data and is computationally complex, is rarely used in planning mobility practice (Sevtsuk *et al.*, 2022).

Behaviour patterns and sustainable lifestyles should be considered as a part of a low-emission development pathway based on “Norway’s long-term low-emission strategy for 2050” (UNFCCC, 2020). The current development plans for Nyhavna have not mentioned doing a travel behaviour survey or referring to previous travel behaviour reports.

5.2.2 How Smart is the parking management in Nyhavna?

Cities use smart parking systems as a cost-cutting measure. First, using information from smart parking platforms, drivers may cut their parking search time, reduce pollution, save money by consuming less gasoline, and alleviate traffic congestion. This increases the number of people who utilize public transit and the revenue generated by cities (Lin *et al.*, 2017).

The pick-up and drop-off zones, especially in the case of shared use, are one of the most significant things to consider when creating the urban environment for AVs. Designated space is required to avoid conflicts with the nearby roadways and parking spaces.

Location, style, sign, connectivity, and comfort are all factors to consider when constructing drop-off and pick-up sites. Silva *et al.* (2021) explain these factors in their article about Autonomous vehicles and urban space management;

- These places should be adjacent to building entrances, allowing people to enter or exit promptly. Separated pick-up and drop-off locations are preferred to eliminate conflict areas and improve user flow; however, if space is limited, a combined pick-up/drop-off area might be established.
- The design of the parking spaces should represent the functionality to make it easier to distinguish it from other infrastructure elements.
- The spaces should have signs specifying their delimitations to assist travellers and avoid misuse of the spaces.
- Seamless connections between pick-up and drop-off sites should be built to allow AVs to rapidly pick up another passenger after dropping off the previous one.
- During the waiting period, a high level of comfort is required (benches, phone charging, lighting, internet, etc.). However, with effective demand-capacity coordination, the waiting time may be reduced.

The development plans for Nyhavna have not proposed any designs that are specific to parking for AVs. Nyhavna port is working on autonomous ships and automated ports within the project "Advanced, Efficient and Green Intermodal Systems" (AEGIS) in collaboration with SINTEF, which means future-oriented solutions using the latest technology are noticed.

Based on the Nyhavna quality program, the municipal sub-plan provides for a parking coverage of a maximum of 1 car parking space per residential unit, 0.25 space per 100 m2 BRA (bruksareal) office and a maximum of 1 space per 100 m2 BRA business and service. This norm must be reduced in order to achieve the goal of a car-free district. Large parts of the necessary parking spaces should be collected in dedicated city parking garages close to the access roads to Nyhavna.

A city car park can be developed into a complete mobility house with a complimentary offer such as rental and sharing schemes for bicycles, micro-mobility, carts and cars. Since the mobility houses are planned to be close to the "gates" of Nyhavna, it is important to be designed active and attractive. Parkings are not visually appealing, which adds to the importance of designing the ground level with a more flexible function (Kildal *et al.*, 2020).

Based on the Bikely platform (figure 22), no service for safe bicycle parking in Nyhavna or in its vicinity is provided currently.

Figure 22: Nyhavna on Bikely platform, Screenshot by author

The current parking spaces on the waterfronts of Nyhavna are used for different types of vehicles, including boats, as can be seen in figure 23.

Based on the quality plan of Nyhavna, for small boats, a houseboat port (Husboåthavn) can be established along Ladehammerkaia. A houseboat harbour is considered in the same place or along the west side of Kullkranpiren (Kildal *et al.*, 2020).

The mobility houses and the bus stations are close to the entrances of Nyhavna and distant from the waterfronts. In a scenario of developing public sea-based transportation, travellers need easy access to the sea-based public transport stations from bus stations or mobility houses.

Figure 23: Parking space, source: by author

5.2.3 How Smart and integrated the public transportation services is in Nyhavna?

AtB is supporting an integrated ticketing system for buses, trains, and ferries in Trondheim. Nyhavna has access to two bus stations and one train station. There is the potential to connect Nyhavna to other areas close to the sea in Trondheim with public transport on water. However, the ticketing system for city bike and electric scooters are not integrated.

Providing the opportunity to easily switch between different modes of transport, such as connecting the network of pedestrian and bicycle lanes to the parking lots and bus stations, would encourage people to choose other modes over private cars.

Mobee is a new MaaS platform in the stage of development for testing that shows the possible modes of transport, including scooters, bike, car, bus, trams, trains, taxis, boats, and planes on the map. The service for all these different modes is not available yet.

This research does not require investigating the level of cooperation between providers of different modes of transport in Trondheim. However, the cooperation is helpful in planning for a more integrated transportation network, including Nyhavna port as a provider of transportation service and parking lots in Nyhavna.

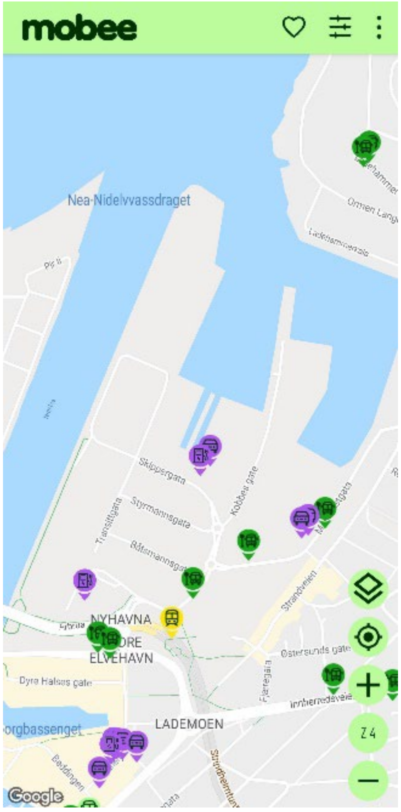

Figure 24:Mobee application services in Nyhavna, Screenshot by author

5.3 Smart travel safety in Nyhavna

Within this chapter, the road fatality and injury rates are chosen as a measure of safety, and the possible smart solutions for Nyhavna travel safety are discussed.

5.3.1 What are the smart solutions to reduce road fatality and injury rates in Nyhavna?

Based on the Road safety plan of Trondheim (2020-2024), Technological measures for safety are proposed as follows :

- Speed indicators around schools.
- Hydraulic bollards as a barrier against illegal car traffic in areas close to the city centre with high pedestrian and bicycle traffic.
- Define a virtual zone where there is a speed limit on electric scooters for rent (geofencing). SINTEF does a pilot project using geofencing (GeoSUM)
- Initiative for collaboration with St. Olavs and the emergency services, as well as NTNU and SINTEF, to discuss possibilities for a solution for collecting data on traffic accidents.

The purpose is to get a better data basis for traffic accidents, especially with pedestrians and cyclists, and resources from the other players.

Current problem points in the physical road network in Nyhavna are shown in figure 25.

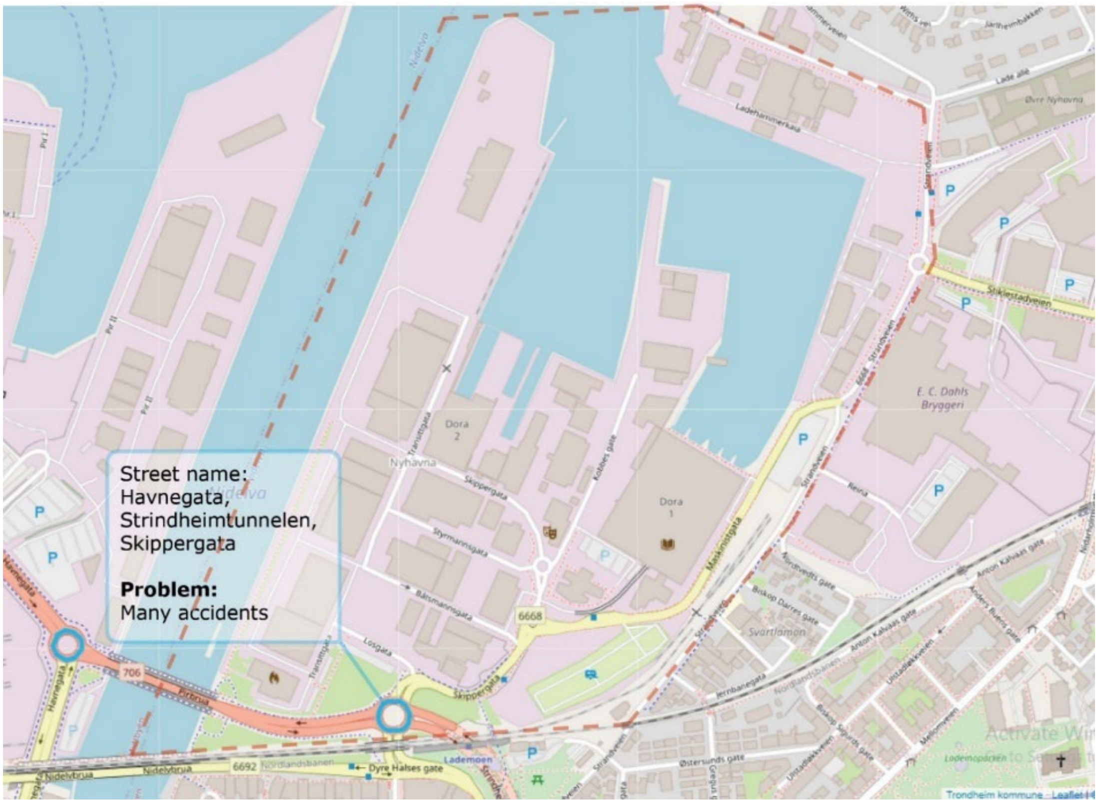

Figure 25: possible problem points in the action program (Map edited by author)

There are no measures suggested specifically for Nyhavna in the quality program for Nyhavna.

The problem point that is spotted in the map above is one of the main proposed entrances or gates to the Nyhavna. At the same time, a walking underpass is suggested that connects the problem point with many accidents to the outside of Nyhavna through Dyre Halses gate.

From an urban planning perspective, and based on the observations, connecting a walking pathway directly to a street with heavy car traffic is not safe. The street hierarchy does not seem to be considered. The underpass is illustrated in the development plans of Nyhavna, which include social activities. The safety level of this underpass is not evident. The proposed illustration and its access are shown on the map in figure 26.

Figure 26: The proposed underpass location on a map, Map source: Google earth edited by Author, Illustration by Mad Arkitekter (2019)

The street lighting to optimise the safety of travellers is mentioned in the quality program. Yet, it is mainly focused on raising urban space quality by light affects on trees, fountains, and monuments, and not specifically with the aim of increasing road safety.

5.4 Smart infrastructure in Nyhavna

This sub-chapter is questioning the required smart infrastructure for logistics, emergency services, prevention measures for environmental predicaments, and controlling environmental pollution.

5.4.1 How smart is the transportation infrastructure in the prevention of natural hazards?

Natural disasters will be more frequent as a result of climate change. Natural disasters pose a serious threat to human life and health, as well as key infrastructure and society functions. As a result, natural hazards and climate change must be accounted for in planning and decision-making. The technical regulations for building and construction (TEK17) provide flood and landslide safety standards. In addition, the DSB has released guidance for municipal planners on how to deal with sea-level rise and storm surges (DSB, 2020). Although it is general to all Norwegian cities, the national safety standards and the local guidelines must be applied in every development plan.

Nyhavna is low, and any surface water from surrounding districts can have consequences for Nyhavna. Good drainage infrastructure for the streets and pathways is needed. For extreme precipitation management, there must also be flood roads that can quickly and efficiently carry the excess flood water from streets, squares, and roofs to the fjord. A location for surface water treatment along Transittkaia is considered to purify the surface water before directing it to the fjord (Kildal *et al.*, 2020). Dealing with heavy snow and ice on the streets and sidewalks is not new to Norwegian cities. Yet, the problems caused by it are not easy to be solved. Elvik *et al.* (2019) analysed the risk of pedestrian falls in Oslo, Norway. The risk of falling per million kilometres walked varies by age, gender, and surface condition. The presence of snow or ice on the walking surface is associated with more than a doubling of risk (Elvik *et al.*, 2019).

The road heating and de-icing system have been long used in Trondheim. Yet it is not possible or economically efficient to apply it in the entire open spaces of Nyhavna. The development plans have not identified the routes with a priority to using the heating technology.

Smart transportation for emergency services is essential to be planned in advance of the development, such as contingency planning for possible scenarios of natural hazards in Nyhavna. In a hazardous situation that exposes people and urban constructions to risk, fast and safe transportation is needed. Except for the Bicycle and walking routes that are specifically designed for pedestrians and cyclists, other streets have car access with strategies to keep the car traffic in the neighbourhood at its lowest. The quality program (2020) states that all unnecessary car traffic should be avoided, but car access for emergency reasons will be provided. Residents' access to emergency services and evacuation management strategies should be well-thought.

5.4.2 How Smart is the logistics delivery in Nyhavna?

Smart urban logistics (SUL) is a system that helps cities become more livable, sustainable, secure, safe, accessible, transparent, strong, and flexible by integrating advanced technology into urban logistics activities like freight transportation, distribution, and storage. It does so by taking into account the expectations of all stakeholders (Büyüközkan *et al.*, 2021).

Goods delivery solutions are planned for the sub-areas so that it limits unnecessary driving with heavy vehicles in the Nyhavna future plan. Based on the quality program for Nyhavna (2020), The port provides an advantageous transport mode for the delivery of goods or construction material so that the traffic congestion caused by delivery will be avoided.

The SUL solutions are various but outside the scope of this study. However, it should be noted that one of the solutions mentioned in the quality program of Nyhavna is electric cargo bikes.

Nyhavna quality program (2020) suggests that there should be a proper parking area for larger cargo bicycles.

As mentioned earlier in 5.1.1 and 5.2.2 sub-chapters, smart logistics for sea-based transportation is being researched currently.

5.4.3 How is Nyhavna dealing with the pollution caused by traffic?

Noise from road traffic is expected to be highest along Riksveg 706 and Maskinistgata. The northern part of Transittkaia will, as a port area, be adapted for heavy transport. This area is only used occasionally, and other social activities such as festivals are suggested while the area is unused. To avoid conflict with the port activities, the quality program suggests solutions such as a "timeshare port", or a division of the port area between long and short notice periods for the arrival of goods, which can enable a greater degree of joint use between port and city (Kildal *et al.*, 2020).

Other than road noise pollution, the noise that is caused by railways (figure 27), port activities, and heavy equipment transit due to construction work can be disturbing for current neighbourhoods and future Nyhavna residents. Vegetation as a noise reduction measure is suggested by the quality program for Nyhavna. Other smart solutions to alleviate the issue should be investigated.

Figure 27: Nyhavna railway. Source: Author

5.5 SWOT analysis of urban mobility in Nyhavna

The SWOT approach is a way of categorizing the internal and external aspects of a complex system such as a city. Internal strengths (S), internal weaknesses (W), external opportunities (O), and external threats (T) are the internal and external qualities in this methodology (Rajput *et al.*, 2021). In this section, a summary of the characteristics and qualities of Nyhavna is provided with the SWOT approach. The qualities are colour-coded based on the four framework factors of sustainability, traffic management, travel safety, and infrastructure. Both the current situation of Nyhavna and development plans are considered in table 7. The states that are marked with a star (*) are proposed by the quality program for Nyhavna.

	Helpful	Harmful
Internal	**Strength**	**Weakness**
	Different modes of transport is available including sea-based transport	transportation network of Nyhavna is not well-connected to the rest of the city
	Developing Nyhavna az ZEN is proposed *	Private car access will be limited inside Nyhavna *
	Mapping GHG emission is porposed *	Weak pedestrian connections between the city and Nyhavna
	Integrated cycling and walking network is proposed *	The proposed underpass connecting DyreHalses gate to Nyhavna is not safe and welcoming *
	Pedestrians and cyclist will be given priority at streed light*	Long intervals between current bus services
	high-speed bicycle route for bicycles is proposed *	Polution caused by heavy equipment traffic during construction
	Access to bus stop within 400 meters for all residents *	Noise polution caused by railway
	Co-locating Mobility house and energy centre is proposed *	
	access to railway and freight train	
	dense vegitation to reduce noise polution is proposed *	
External	**Opportunities**	**Threats**
	Expanding sea-based transport	Streets are prone to flooding due to being flat
	Nyhavna is a flat area which supports cycling and walking	High wave danger
	Short distance to the city center	Noise and air pollution by sea-based traffic
		Heavy snow blocking access
		Rising water level due to global warming
		Road accidents caused by ice and snow

Sustaiability
traffic management
safety
infrastructure

Note: * The proposed state of Nyhavna is concidered, not the current state

Table 7: SWOT analysis of smart urban mobility in Nyhavna, By author

6 Findings and implications

In this chapter, the findings of the analysis are discussed using the framework structure. Finally, the results are used to answer the questions of the research.

6.1 Discussing the link between urban planning and smart mobility in Nyhavna

Within the theory chapter, I developed a framework as the foundation of my research to analyse the case study based on that. The documents that are used as the primary source of data were introduced in the context of the study. The main document that is used is the quality program of Nyhavna. The urban planning office of Trondheim municipality prepared this document to build a framework for future transformations in Nyhavna. To analyse smart transportation, I categorised the gathered data based on the smart mobility framework for Nyhavna and assessed the data from an urban planning perspective. The SWOT analysis was provided to give a better overview of the smart urban mobility state in current Nyhavna and the future Nyhavna.

6.1.1 The smart urban mobility in Nyhavna based on the framework

The main findings classified based on the framework from an urban planning perspective are as follows:

- Smart, sustainable mobility in Nyhavna:
  The plans for the development of Nyhavna, along with the national and regional transportation plans for the forthcoming years, have the goal of zero-emission in common. There are different strategies proposed by the development plans, including reducing energy consumption and using clean energy for transportation. The concept of ZEB has long been practised. Developing Nyhavna based on the ZEN concept shows the significance of following the Zero-emission goal beyond the building scale and to the neighbourhood scale. Fortunately, smart innovations to fulfil the energy sustainability goals are increasing rapidly. Yet, applying the zero-emission goal to transportation planning is more complicated. There are no specific boundaries for mobility networks. So, there is no closed system to calculate the energy consumption and GHG emissions within the system. It becomes even more complicated when realising that not only it is inevitable, but also it is necessary to remove the gaps in the transportation network and make it as seamless as possible. The Nyhavna area is planned to be a new city centre and attract a large population from outside of the area. It is a huge challenge to increase the

travel numbers and at the same time, keep the GHG emissions at zero level. The proposed method of mapping the GHG emissions and sharing it with residents will increase awareness of energy consumption for certain, but it is not a promising strategy for lowering energy consumption. From the technical aspect, mapping the energy consumption, following the GHG emissions using sensors, generating clean energy, and providing E-scooter and E-bikes and chargers for them are all very helpful. But the question would be, how do we guarantee people's travel behaviour will be as planned?

It is impossible to assure the success of the development plans since human behaviour is not easy to be predicted. Yet, urban planners can contemplate the feasibility of smart technological solutions as well.

Here, I bring forward the uncertainties that I encountered during the analysis of smart, sustainable mobility in Nyhavna.

One of the measures to reach the zero-emission goal is to reduce travel time and prevent delays or stop times of vehicles that add up to the GHG emissions. At the same time, giving priority to pedestrians at traffic lights increases the delay times of these vehicles. It is important to find a balance between prioritising pedestrians and cyclists and keeping car traffic delays to an acceptable level. Finding the measures to optimise the travel time for car users and at the same time for pedestrians and cyclists is beyond the scope of this study. Nevertheless, too much waiting time for any of the travellers with different choice of modes of transportation might lead to discouraging them from using this area.

The quality program suggests building a mobility house providing parking areas for different vehicles together with charging stations. It is expected that not only travellers from out of Nyhavna, but also Nyhavna residents, and more particularly residents without private parking places, are going to use the mobility house to park their vehicles. The solution is very interesting considering that the location of the mobility house is to be close to the access points of Nyhavna to prevent the traffic from getting inside the neighbourhood. However, locating the mobility house at the "gates" of Nyhavna increases the distance from residential buildings to the mobility house and decreases the chance of residents parking their cars farther from their housing units. As mentioned earlier, despite the impossibility of predicting the resident's choice, it is possible to try to reduce the chances of failure as much as achievable. The quality program team has been aware of this issue and suggested designing the mobility house to function more flexible for the times that it is not being used as a parking area.

The quality program mentions the significance of promoting walking and cycling repeatedly. There are not many details provided on the measures that are going to be taken to make the routes for pedestrians and cyclists more attractive and safer. Unfortunately, the study area has no residents currently. Therefore, it is not possible to get feedback and reflection from the residents' perspectives. There are standard measures to be used, such as maximum walking travel times or standard distance to the nearest bus station, such as the 400 meters stated in the analysis. These numbers are not highly promising since human behaviour is too unpredictable to let us be dependent on the standards. Yet, there are measures that urban planners recommend increasing the chances of people using a specific street, such as adding to the safety, more attractive land uses, designing spaces that support more social activities, and accessibility for all groups.

The current walking and cycling pathways that connect Nyhavna to the city are very weak. The railway functions as a physical barrier and the access points that are named as gates of Nyhavna in the quality program for Nyahavna are mainly underpasses that cross the roads with heavy traffic.

The development plans of Nyhavna have used the urban theories that are introduced in the theory chapter, such as ZEN and 15-minute cities. It is interesting that the planners have adopted smart solutions to these urban concepts. Combining the energy centre with the mobility houses and having citizen observatories follow up on GHG emissions are examples of this combination. Smart measures can be taken for a better implementation of all other recommendations given by the quality programme for Nyhavna.

- Smart traffic management in Nyhavna

The future traffic flow of Nyhavna is not measurable reliably. Whether it is car traffic or pedestrians and cyclists, providing enough data for future transportation planning is a challenge. This increases the significance and seriousness of transportation planning in advance of the developments. At the same time, it can be an advantage for the planners to use the latest technology to optimise their designed transportation network and decrease future reconstruction expenses.

Since Nyhavna travels are planned to be more dependent on cycling and on-foot travels, car traffic is not the only type of traffic to be concerned about. Being able to predict the pedestrian and cyclist traffic flow will give the planners more insight for a more accurate street network design to encourage on-foot travel and cycling. In addition, the transportation network needs to be connected and support various modes of transport. There are various innovations supporting an integrated transportation system. To give an example, Mobee as a MaaS platform, along with physical transportation planning solutions such as park and ride, could increase the chance of travellers using the platform choosing smarter and more sustainable travel modes. The same goes with automated cars, automated public transportation vehicles, smart parking platforms, etc. This requires cooperation among planners and innovative technology developers.

The transportation platforms with various packages of offers can influence travel behaviour. Guiding this behaviour in a direction aligned with urban solutions for mobility problems can be helpful. The service providers want to increase their users. The surveys they do to increase their users might be a good data source for transportation planning. Meanwhile, urban planners can spot mobility problems with the cooperation of residents, and the solutions can be shared with mobility companies and mobility platforms. An example would be parking spaces for micro-mobility devices like bicycles and E-scooters. Both urban planners and mobility service providers investigate the best places for parking these vehicles. Lightweight vehicles such as E-scooters do not need a specific parking space, so they are left in random places. The locations where people tend to pick up or park these vehicles and travel behaviour surveys done by these companies are valuable sources of data for urban planners as well.

- Smart travel safety in Nyhavna

The safety plan of Trondheim locates the intersection of Strindheimtunnelen, Havnegata, and Skippergata as a problem point with many accidents. The roads with heavy traffic and heavy vehicles, especially during construction and transits, add up to the road accident risks. It becomes more serious now that Nyhavna aims to attract a large number of pedestrians and lightweight vehicle users to the neighbourhood. Therefore, it is important to think about the pedestrian and cyclists' road injuries, knowing that the biggest share of road injuries belongs to pedestrians and cyclists. There is no specific smart solution suggested by the development plans. However, the safety plan suggests interesting measures such as a smart speed limit in virtual zones for lightweight vehicles like electric scooters. The virtual zone boundaries can be discussed with planners. They also suggest cooperative initiatives with different organisations such as hospitals to build a database for road accidents which can be very useful. Yet, it is important to figure out how collecting data on the current state of Nyhavna can be useful in planning for future developments.

Road safety is affected by the quality of urban furniture as well. There is not much information on smart lighting in Nyhavna development plans that is worth mentioning as a smart infrastructure to enhance road safety. However, smart lighting systems not only can enhance the safety of the streets but also it can decrease energy consumption. Road safety is mainly measured by the number of accidents and injuries. The safety of Nyhavna was assessed with the same question of how to reduce road accidents and injuries. Although a low number of accidents does not implicate a road is safe. It might be due to avoiding people commuting on unsafe streets. The reasons behind feeling unsafe can be various and complex. Thus, surveys to investigate the safety levels of the streets are required. Detecting the safety problems in the neighbourhoods and the solutions can be done through participatory methods in different stages of Nyhavna developments along with the stakeholders and residents. Smart participatory methods to involve more people in the planning process are useful. A challenge of smart participatory methods is that they should make sure no one is left out.

Other than the measures planned for the entire city of Trondheim in the Road safety plan of Trondheim, the quality plan of Nyhavna or the municipal sub-plan for Nyhavna have not proposed plans for travel safety in Nyhavna.

- Smart infrastructure in Nyhavna

Transportation infrastructures are built for long-term use and the huge costs of building and maintaining or changing them increase the importance of planning thoroughly in advance. Nyhavna’s transportation network is not completely disconnected from the rest of the city. Yet, Nyhavna, due to its proximity to the fjord and being flood-prone, requires different infrastructure. The quality program of Nyhavna advises a good drainage system along with a location for water treatment. During the cold seasons, the heated de-icing system that is used in the Trondheim pedestrian network is useful. In spite of this, the routes with higher priority to be snow-free such as the pedestrian routes, connecting mobility houses to residential units, and main public spaces with the highest number of pedestrian commuting, should be identified. Therefore, not only will the infrastructure be more economical, but also the chances that more people will choose on-foot travel modes will increase. Collecting more data to predict pedestrian traffic after the development of Nyhavna can be helpful in controlling the heating system and optimising the energy consumption for heating the streets and sidewalks. Another notable insight from the quality program is taking advantage of sea-based transportation modes. Port activities are not residential neighbourhood-friendly due to the noise pollution and unappealing environment with the least urban activities. However, it can take the disturbing transportations such as construction material transit out of the neighbourhood. In other words, it prevents heavy equipment from commuting inside the neighbourhood. Smart timeshare for port activities is also a smart solution suggested by the quality program.

The zones with limited car access might use smart hydraulic bollards as suggested by the road safety plan of Trondheim (2019) to prevent car traffic but allow emergency access at the same time. For emergency occasions and while facing natural hazards, contingency planning is needed. In extreme cases like flooding, with the necessity to evacuate the neighbourhood or drain the accessibility network, quick access to safe zones should be predicted.

Overall, the smart urban transport infrastructures are various, and only the solutions suggested by the development plans of Nyhavna within the research framework are discussed in this study as single examples.

6.1.2 Summarizing the role of urban planners in smart urban mobility

To sum up, the cooperation of the teams working on smart city solutions for transportation with urban planners seems to be important. In addition, further cooperation with other related organizations will be helpful. Within this study, transportation companies, academic research groups, mobility platforms, and the healthcare system are mentioned to help with providing data and developing initiatives to take smart solutions to the next level. Urban planners' cooperation in this process increases the quality of the smart urban mobility solutions by;

- Considering the impact of human behaviour,
- Increasing the equity among travellers,
- Increasing travel safety,
- Involving citizens through participatory methods,

- Providing smart, flexible alternatives for different development scenarios,
- Finding out what kinds of data are needed to enhance the quality of urban mobility,
- Finding out how and from whom the required data can be collected,
- The technologies that can be employed to work out urban mobility problems
- Finding the links among stakeholders which their cooperation will facilitate the problem-solving process,

The cooperation must be two-sided to be successful.

The mobility companies and other smart mobility services can ask for the requirements to increase the effectiveness of their initiatives which consequently enhances the efficiency of urban mobility.

The development of Nyhavna is a long-term plan. The construction will continue after the first group of residents move to Nyhavna. There are solutions that are planned to be implemented to solve Nyhavna mobility problems, as mentioned earlier. However, urban issues are wicked problems. It is important to build cooperation with residents from the early stages to go through the problem-solving phases along with other stakeholders.

6.2 Recommendations for smart urban mobility in Nyhavna from an urban planning perspective

This sub-chapter gives suggestions for every four framework factors as examples of connecting urban planning to smart city solutions. The smart urban mobility application cases are manifold. Therefore, the list cannot be comprehensive. However, these few examples are given to bring forward a better understanding of the potential of bridging urban planning to smart urban mobility solutions.

- Smart citizen observatories and participatory mapping (such as the proposed emission testing/ pollution sensors) to follow up on the consequences of choosing different modes of transport while providing citizen science. At the same time, this method is used as an educational tool for citizens, raising awareness towards the sustainability of their urban travels. As explained in the theory chapter, providing a citizen observatory and smart participation methods to engage citizens are recommended.

The quality program of Nyhavna has mentioned suggesting preparing an educational and visual greenhouse gas and energy monitoring system that is implemented in every building, business and housing unit. Users and residents are involved in that and gain an understanding of how their own energy use and production contribute to achieving the goal of zero emissions (Kildal *et al.*, 2020). But this method is in building scale only. Yet it can be implemented for transportation monitoring energy use and GHG emissions. In addition, citizen observatories provide the opportunity for citizens to give feedback and for urban planners to use the feedback and share them with decision-makers.

- A mobility house is a smart and sustainable solution, especially if it is co-located with an energy centre. Yet, new public spaces such as mobility houses without previous history of success in attracting people should have alternative plans. Planning for flexible public spaces to support diverse activities, such as the proposed solution for mobility houses in Nyhavna, is recommended. The ground floor of the mobility house is suggested to be used for social activities if it is not used as a parking area as planned.

  Another example of the need for flexible design for urban spaces in Nyhavna is the northern part of Transittkaia, which is used as a port area but is suggested to be used as a public space as well. Smart urban logistic solutions can be used to implement the "timeshare port" idea. This will make planning easier to avoid interference between diverse industrial and social activities.
- Providing low-emission vehicles and different platforms to use a bus, city bike, E-scooter, etc., separately does not guarantee people's interest in them. It is important to make sure the routes for all transportation modes are well-connected, attractive, and safe not only for the users of the mentioned vehicles but also to provide easy access to sustainable travel for the pedestrians. In addition, the accessibility for older people and physically challenged people should be investigated. The maximum distance of 400 m should not be the only measure for locating the bus stations. The smart technologies used for public transportation platforms or travel planning platforms should also consider all people with special needs as well. Cooperation among the providers of these services and the planners is required. This cooperation is helpful for a more seamless accessibility network and further in locating better spaces for parking areas and charging and maintenance stations. The park and ride strategy implemented in Trondheim for parking cars and bikes near some of the bus stations is suggested for Nyhavna. The parking spaces can provide space for other modes of transport such as E-scooters. The MaaS platforms (e.g., Mobee in

Trondheim) can be involved in this process to help investigate why the users use or do not use the specific connecting travel modes.

- In a case like Nyhavna that is not developed yet, predicting the traffic flow for both vehicles and pedestrians with high accuracy is not possible. But analysis tools like digital twin or GIS can provide various results based on the given dataset.
- One of the strategies of the quality program for Nyhavna to encourage walking and cycling is giving them priority at traffic lights. One smart way is installing sensors that can distinguish cyclists and pedestrians to give them priority at traffic lights without the requisite to press the pedestrian crossing button. This would be possible by having access to enough real-time data provided by sensors and other connected devices such as public transport vehicles or automated E-bikes, E-scooters, etc. This can be of use to optimise the time intervals of traffic lights and traffic optimisation. But the factor of the levels of priority of different types of transportation modes should be investigated by transportation planners and urban planners before being employed in the smart traffic light system.
- In case mobility house is successful enough to prevent people from using on-street parking spaces, these parking areas might be left unused. A smart solution would be a flexible design considering the required infrastructure to use the area to park or charge E-scooters and E-bikes with a convenient waiting space along.
- Although mobility house and street-side parking areas are considered for cyclists, SykkelSafe service as a safe bicycle parking space with shelter for both standard bikes and cargo bikes in areas to cover the needs of areas that are distant from mobility house is recommended.
- A smart speed lowering system which is already used for E-scooters to control their speed for safer travel is useful for Nyhavna. Defining the low-speed zones is recommended.
- Due to the proximity to the fjord, Nyhavna is dealing with the dangers of wave impact and low-point flood-prone areas. The technologies to better handle the risks caused by high waves and flooding and the physical solutions to lead surface water to the fjord are helpful. Smart solutions to alert the dangers in advance and educating residents on Nyhavna within a contingency plan are recommended.
- Smart street lighting to increase safety while decreasing energy consumption is recommended.
- An interesting suggestion by the Road safety report, as mentioned earlier, is to support initiatives with the cooperation of academic organisations and hospitals to gather data for

increasing road safety. Participation of urban planners might be useful for both the initiative team and urban planners. This is an example of smart cooperation by making a database with the help of related organisations and then analysing them with the help of professional academics. Urban planners can use the result of these initiatives to increase the quality of their plans.

- The charging stations that are easily accessible are considered in the quality program. Yet, people can be encouraged to use them by providing easy access for all people with different needs, urban furniture for waiting times in different weather conditions, and at the same time considering smart sustainability solutions to reduce the energy price such as locating the charging stations close to the green energy generating infrastructures such as solar panels on parking rooftops.
- Roads should be designed to be easier to read for automated vehicles. The guideline of such a street design is beyond the context of this study.
- Identifying the routes with the priority of using the de-icing heating system to keep the routes safe and clean.
- Safe pathways for pedestrians and cyclists that connect Nyhavna to its surrounding is required. The street hierarchy should be considered along with other safety strategies, such as reducing car speed and car access close to the entrances of Nyhavna.
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6.3 Discussing the questions of the research

This research has tried to investigate the questions of the research through a set of methods. In this section, it is investigated whether the questions are answered.

- *Should urban planners have a role in planning for smart urban mobility? If the answer is positive, how can urban planners contribute to smart urban mobility?*

The solutions that smart urban mobility suggests for urban mobility problems fail to include complicated social aspects of urban issues, such as the reasons behind diverse travel behaviour. Citizens' participation in developing smart urban mobility is often disregarded. Urban planners' insight into smart urban mobility can improve the quality of the mobility solutions and increase the chances of successful planning. However, due to the multidisciplinary nature of urban planning, the responsibilities of urban planners are not easily defined. The extent of the urban planners' involvement in other fields (smart urban mobility in this case) can not be determined. Yet, the collaboration among them has positive results for both. The possible answers to this question are given within the bullet points stated in sub-chapter 6.1.2.

- *How can urban planners employ smart urban mobility solutions?*

The benefits of using smart urban mobility solutions for urban planners are manifold. Smart urban mobility solutions can provide technical tools for urban planners for better and more accurate planning. Urban planners can use the data collected through smart mobility solutions as well. This collaboration leads to the development of smart mobility platforms to function as a virtual participatory platform among their users. The users of smart urban mobility platforms can reflect on their travel experiences and provide feedback. These feedbacks are a source of information for urban planners to identify urban mobility problems. Smart urban mobility can provide potential solutions or support to urban planning in many ways, and fortunately, new solutions are progressing rapidly. Thus, the possible instances of how urban planners can employ urban mobility solutions are not limited. The answer is highly dependent on the urban planner's creativity and the ability to link the related stakeholders and sources of data to the correct urban subject. In this manner, urban planners should keep themselves updated with recent advancements in the smart cities field. Being constantly updated in all related disciplines to urban planning does not seem to be feasible. However, it can be an advantage for them. Throughout the literature review, I have noticed that each smart mobility solution opens the door to broad sources of information. The limits between the relevant and irrelevant information for urban planners are extremely hazy. So urban planners' responsibility is to find useful connections rather than extending their knowledge in relevant fields.

- *How can urban planning prepare the ground to develop smart urban mobility in Nyhavna?*

Based on the answers to the previous questions, one of the most important roles of urban planners while creating development plans for Nyhavna is to build collaboration among; Nyhavna stakeholders, urban mobility service providers, the mobility initiatives, and the other related organizations that their information are helpful (e.g. the suggestion by road safety plan which states that the information hospitals can provide about road injuries and fatality can be helpful in increasing travel safety). Regarding the Nyhavna case, cooperation is recommended among; Nyhavna port, mobility service providers of Trondheim, mobility platforms and mobility initiatives (such as Mobee and Bikely, City Bike, etc.), academic and research organisations (such as SINTEF, NTNU, MARINTEK), Smart city projects such as +CityxChange. The answers to this question are within the recommendations given in the previous sub-chapter 6.3.

6.4 Need for further investigation

Each of the factors that are used within the proposed framework can have more indicators to evaluate smart urban mobility in depth. An extensive evaluation framework for smart urban mobility is required. However, these frameworks cannot be universal and should be localized separately for each case. Also, a more comprehensive result needs side-research in each aspect. Some of the examples that can be further investigated are as follows;

- Smart solutions to manage using city ports to be mixed-use such as an urban space (e.g. Timeshare port), can be helpful for Nyhavna and other ports inside the cities.
- The requirements to develop a smart port to facilitate urban travel and logistics.
- It should be further investigated if the streets are designed for the needs of low-emission vehicles and automated vehicles. Also, a more functional street design to support AVs can be researched.
- The requirements for SUL solutions that are within urban planners' knowledge to facilitate the implementation of SUL can be investigated in another study.
- The required infrastructure and standards in transportation networks to help self-driving bus service providers give citizens a better service can be investigated.
- Research on the necessity for policy change to boost filling the gap and link urban planning and smart cities and, more specifically, in the urban mobility field can be helpful.

6.5 Conclusion

From what I learned within this research, in addition to what I learned from studying Urban Ecological Planning, urban planning is not a static knowledge. It is a dynamic multidisciplinary field which sees a city as an organism and not a mechanism (Sliwa *et al.*, 2018). Yet, most of the work that has been done to develop smart urban mobility is based on the city as a mechanism. Planning smart is not about employing technology only. For instance, a digital twin of an urban transportation network is not a 3D model of this network. The data given to this model, the methods used to analyse the data, and the application of the results are converting the 3D model into a tool for urban planners. Adding human aspects and involving the citizens and stakeholders in the process is what urban planners can bring forward to smart urban mobility. Planning smart is about wisely using it as a tool that serves the needs of citizens and increases the quality of their urban life.

The synergy between urban planning and smart urban mobility is a collaboration that strengthens and supports them both. The Nyhavna case has displayed examples of how this collaboration works within the smart urban mobility framework. However, the framework has limits which were identified throughout the research progress. Developing a more comprehensive and, at the same time, flexible smart urban mobility framework in the urban planning context requires further investigation. This thesis does not claim that urban planners can develop smart urban mobility in Nyhavna through the thesis recommendations alone. The thesis indicates that such recommendations can help urban planners address urban mobility issues better through smart solutions.

7 Reference

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