URBAN PLANNING: THE POTENTIAL ROLE OF SHARED AUTONOMOUS VEHICLES IN TRANSFORMING OUR CITIES

BASED ON
A CASE STUDY OF STAVANGER CITY CENTER

A MASTER'S THESIS

IN

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MASTER'S THESIS

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DEDICATION

Mom, your wish was to see me succeed in my studies and life.

You believed in me.

I would like to say to you: I did it, mom.

I would like to dedicate this master thesis to my mother:

HIWET GHEBRESLASSIE RETA.

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ABSTRACT

THE POTENTIAL ROLE OF SHARED AUTONOMOUS VEHICLES (SAVs) IN TRANSFORMING OUR CITIES: BASED ON A CASE STUDY OF STAVANGER CITY CENTER BY MILLION KIROS WELDU

Shared Autonomous Vehicles (SAVs) presents new opportunities to solve mobility and environmental problems, and new challenges in restructuring the transport infrastructures. The integration of the vehicles could reduce traffic accidents, increase mobility and reduce congestion. The master thesis aims to unravel the new possibilities and opportunities to transform mobility and investigate urban land use. It has also focused on the potential of transforming the city with new ideas and developing technologies.

The thesis has research questions:

"How could SAVs be integrated to help achieve sustainable mobility?"

And

" How could SAVs impact the urban land use and mobility in Stavanger City Center?"

The thesis investigated the impact of SAVs on Stavanger city center with an overall goal of transforming the mobility to sustainable mobility. The thesis investigated the requirements and barriers to the integration of SAVs or Autonomous Vs. It covered the challenges in the technical requirements in vehicle development and the infrastructure, standardizing challenges in Norway and internationally, and legal barriers to integrate the vehicles.

The thesis further analyses the requirements and barriers to create a strategy and intervention for the integration of the vehicles. The thesis interviewed ten very influential people related to the development of the vehicles, people related to standardizing and regulating the vehicles and people related to the implementation of the vehicles.

"Everything … affects Everything"

Jay Asher

The findings showed that everything affects everything. The technical development is developing very fast, and the ever-changing development is making standardizing and regulating the vehicles difficult. Not having regulation is also delaying the integration of the technology and the Original Equipment Manufacturers (OEMs) are keeping the technological development status secret. Moreover, integrating SAVs would require all parties to work together.

Additionally, the thesis analyzed the impact of SAVs in the city center of Stavanger municipality. It investigated the impact of SAVs in land use and mobility in the city center. The thesis analyzed:

- The impact in parking areas
- The impact on transport infrastructures
- The impact of SAVs in the attractiveness and livability of the city center.

The thesis found out that in the transition time removing 40% of the total number of parking registered in Stavanger city center could potentially free an area corresponding to 7 football fields. The analysis showed that SAVs could free the city center from car jam-packed streets and congestion. The impacts all lead to freeing area in the city center which could promote new development and improve livability and attractiveness of the city center.

The thesis further analyzed the potential scenarios of integrating SAVs in the city center. It analyzed the alternatives and recommended to implement SAVs as an integrated part of the public transport in a mixed mobility paradigm. The thesis also selected possible routes and mechanism to integrate SAVs.

The thesis concluded that SAVs could change the Stavanger City Center. They would free area and provide space for change. The change in the city center does not solely depend on the integration of SAVs, but on how the society wants to move and live in the city center. SAVs could provide opportunities to improve the accessibility and reduces the burden on the demand for parking areas in cities.

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LIST OF ACRONYMS AND ABBREVIATIONS

AVs	Autonomous Vehicles
SAVs	Shared Autonomous Vehicles
CAV	Connected Autonomous Vehicles
CCAM	Connected Coordinated and Automated Mobility
VKT	Vehicle Kilometer Travel
ITS	Intelligent Transport Systems
NTP	National Transport Plan
V2V	Vehicle to Vehicle
V2I	Vehicle to Infrastructure
ERTICO	European Road Transport Telematics Implementation Co-ordination Organization
PRT	Personal Rapid Transit
NPRA	Norwegian Public Roads Administration
OEMs	Original Equipment Manufacturers
ADAS	Advanced Driver Assistance Systems
TØI	Transport Economy Institute
KSI	killed or seriously injured
ECUs	Electric Control Units
MCUs	Micro-Controller units
ACC	Automatic Cruise Control
FCW	Forward Collision Warning
AEB	Automatic emergency brake
LDW	Lane departure warning
ISA	Intelligent speed adaptation
GPS	Global Positioning System
CEN	European Committee for Standardization
ETSI	European Telecommunications Standards Institute
ISO	International Standards Organization
BSI	British Standard Institution
TSC	Transport Systems Catapult

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CHAPTER – ONE

AUTONOMOUS VEHICLES AND BACKGROUND INFORMATION

Figure 1.1- Stavanger City Center http://www.google.no/maps/

1. CHAPTER ONE – AUTONOMOUS VEHICLES AND BACKGROUND INFORMATION

1.1. INTRODUCTION

The integration of Autonomous vehicles or Shared Autonomous Vehicles in cities presents with new opportunities and new challenges to solve mobility and environmental problems. The presumed benefits are that the vehicles could reduce traffic accidents, increase mobility and reduce congestion. Moreover, the master thesis aims to unravel the new possibilities and opportunities to transform mobility and investigate urban land use. It has also focused on the potential of transforming the city with new ideas and developing technologies.

The thesis investigated the impact of SAVs on Stavanger city center with an overall goal of transforming the mobility to sustainable mobility. The thesis investigated the requirements and barriers to the integration of SAVs or AVs. It covered the challenges in:

- Technical requirements in vehicle development and infrastructure
- Standardizing challenges in Norway and internationally
- Legal barriers to integrate the vehicles.

The thesis further analyzed the requirements and barriers to create a strategy and intervention to the integration of the vehicles. The thesis interviewed ten people related to the development of the vehicles, people related to standardizing and regulating the vehicles and people related to the implementation of the vehicles.

The thesis analyzed the impact of SAVs in the city center of Stavanger municipality. It investigated the impact in land use and mobility in the city center. The thesis analyzed:

- The impact in parking areas
- The impact on transport infrastructures
- The impact of SAVs in the attractiveness and livability of the city center.

The thesis further analyzed the potential scenarios of integrating SAVs in the city center. It analyzed the alternatives and recommended to implement SAVs as an integrated part of the public transport in a mixed mobility paradigm. The thesis also selected possible routes and mechanism to integrate SAVs.

1.1. URBAN MOBILITY

The master thesis is part of the master program in the department of town planning and urban design for spring 2018 . The development of Autonomous vehicles has opened a new opportunity to provide sustainable mobility. The thesis focuses on self-driving vehicles as a public transport mode. Moreover, this thesis aims to investigate how Self-Driving vehicles could change our cities and transform the transport system.

It requires the knowledge and understanding of Self-Driving cars to study the impact they have on the society. Even though there is uncertainty surrounding the autonomous vehicles, it is necessary to understand how we could integrate them into the existing traffic system. It is also essential to investigate the challenges they could impose on the transportation system, and what their strength and weakness are.

When Autonomous Vehicles will be allowed on the streets is not that far away. History shows a similar pattern when the auto vehicles first introduced in 1900. The figures below show how people's preference changed, and the auto vehicles replaced the horse wagons. The difference on the change was within a couple of years. Figure 1.2 was taken at New York City in 1900. The horse wagons occupied the streets, and there was one auto vehicle

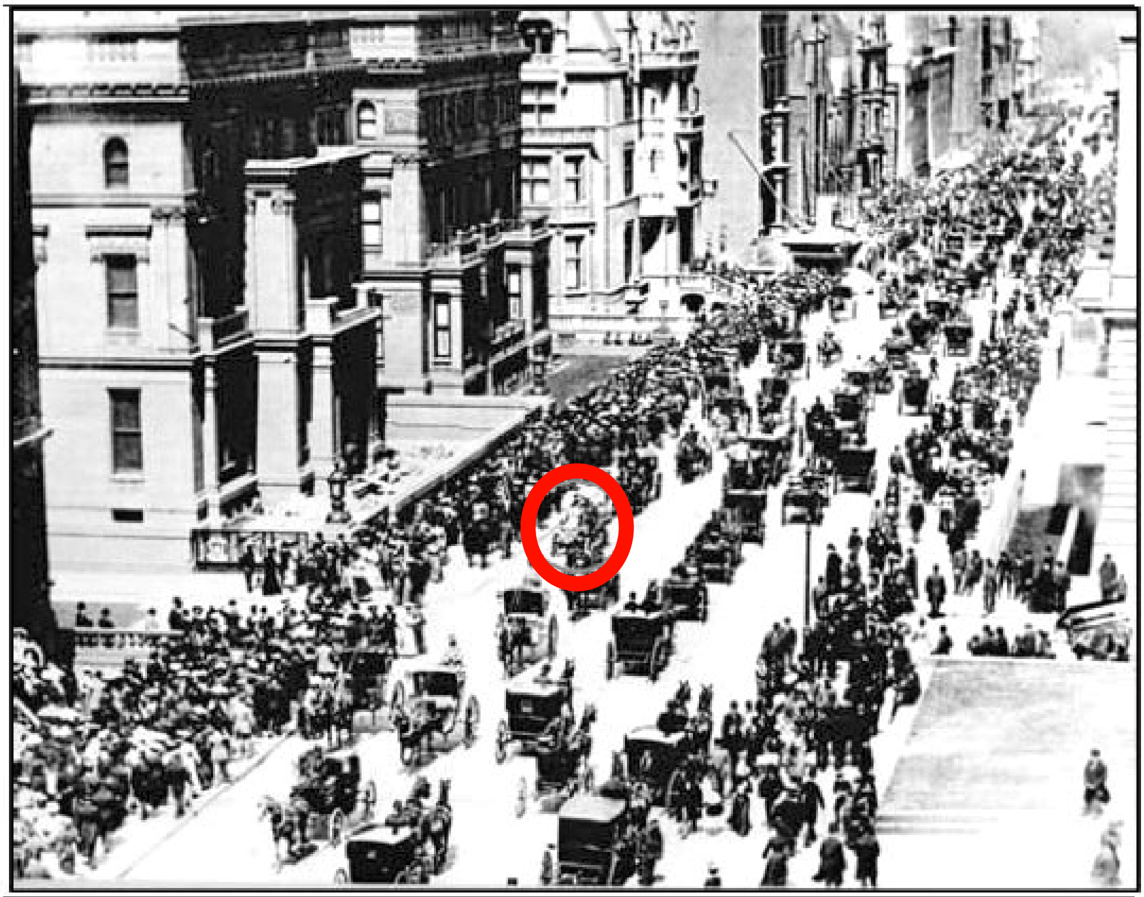

Figure 1.2- Horses dominating the street on 1900 – Source: http://i.pinimg.com/originals/78/7c/7c/787c7ce67a269f6c1ab2165c6b833ceb.jpg

in the middle. On the contrary, figure 1.3 was taken on New York City in 1913 where the auto vehicle had taken the streets with only one horse wagon among them.

Figure 1.3- Cars dominating the street on 1913 – Source: http://www.hydrogencarsnow.com/wp-content/uploads/2017/01/easter-morning-1900-new-york-city_s-fifth-avenue1.jpg

At present, technological advancement in the auto industry is making self-driving vehicles a reality of the near future. Moreover, 11 largest automakers are planning to have a fully autonomous vehicle on the road between 2018 and 2021. (American Planning Association, 2017) The autonomous vehicles can disrupt the transportation system in many ways. It could facilitate better mobility allowing people with restricted access to public transport get services that suit their activities. On the contrary, they could initiate a privatized mobility system where they take away people from the public transport.

The technological innovation in the auto industry could reduce traffic accidents and manage traffic congestion. The new vehicles are using the technological developments to increase traffic safety. The technology is an essential component of the Autonomous vehicles. Moreover, Autonomous vehicles further increase the traffic safety by eliminating the human error. Autonomous vehicles are not out in the streets for people to benefit. It is necessary to be familiar with the different automation levels of the auto industry and keep in mind that their impact could also vary from city to city.

1.2.1. WHAT ARE AUTONOMOUS VEHICLES?

Autonomous vehicles (AVs) are vehicles which can operate without the influence of a human driver. (Techopedia, 2017) AVs use different sensor technologies for the operation of driving such as Supplemental sensors, vision system, Lidar system and Radar system. Figure 1.4 shows Easymile Shared autonomous Vehicles (SAVs) sensors demonstration picture. Those functions help on sensing and seeing the surrounding and have a 3d image of the world. (Veg,-og transportavdelingen Samfunn, Region sør, 2017) However, Self-driving vehicles or AVs vary in their degree of automation. A fully AV is a vehicle which can navigate without the complete intervention of human on the travel from A to B. Automated vehicles have different technological and functional levels defining the degree of their automation.

The six levels of automation describe the possibility of the different types of car assistance that could be used in the transport systems. The thesis is only considering Level five- fully automated vehicle. Level five AVs are not available to the public yet. So, public acceptance and direct benefits of the vehicles is not entirely possible to be measured.

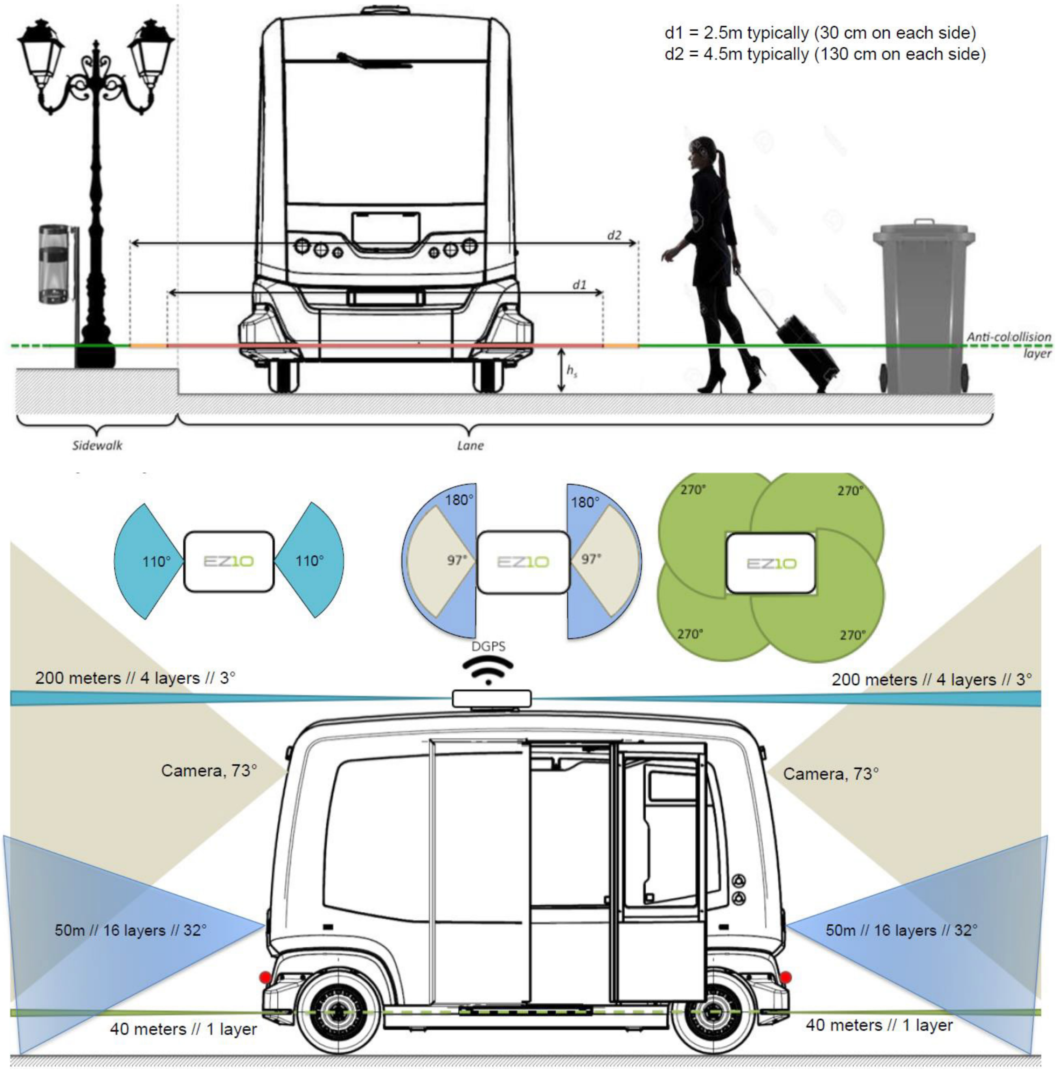

Figure 1.4- Shared Autonomous vehicle (Veg,-og transportavdelingen Samfunn, Region sør, 2017)

LEVELS OF AUTOMATION

I. Level Zero – No Automation - This level of AV describes that the vehicle has no automation. A human driver fully controls the vehicle in all its aspects of the steering, brakes, throttle, and power. (Reese, Hope, 2016)

II. Level One – Driver Assistance - This type of vehicles are vehicles with one or more specific control functions are automated, but the driver has the overall control and responsibility for its safe operation. Examples of level-one automated vehicles functions include cruise control, automatic braking, lane keeping, and park assist. (Jason Wagner, January 2014)

III. Level Two – Partial Automation - This type of vehicles are vehicles that enable the driver to physically disengage from multiple aspects of the driving task simultaneously. In this kind of vehicles, the control system and monitoring of the vehicle work in automated, but the driver must be available to take over control of the vehicle at any time and is the primary responsibility for safe operation road monitoring. It is a kind of vehicle where you can have your hands off the wheel, but your eyes must be on the road, e.g. Tesla's Autopilot. (Jason Wagner, January 2014)

IV. Level Three – Conditional Automation - This type of vehicles are vehicles that safety-critical functions under certain traffic or environmental conditions are operated autonomously. In such vehicles, the driver does not need constantly to monitor the road, but the driver must be present to take control in circumstances where the vehicle cannot operate safely. (Jason Wagner, January 2014)

V. Level Four – High Automation - This type of vehicles are vehicles where they can drive fully autonomously under certain right circumstances but needs a driver to be present in the vehicle. Although the vehicle can drive safely by itself, it can also ask for assistance when a situation encountered which make driving difficult. The vehicle will park by itself if no assistance is present from the driver in order not to put the passengers in danger. E.g. of such vehicles are Waymo's test cars. (Loz Blain, 2017)

VI. Level Five – Full Automation - This type of vehicles are vehicles which can operate all safety-critical driving functions and monitoring roadways for the entire trip at all conditions. The steering wheel is optional on this type of vehicles because the vehicle does not need help on the operational matter from the driver. (Loz Blain, 2017)

1.2.2. FULLY AUTOMATED AND SHARED

There are two ways to utilize AVs. One is as privately-owned cars and the second is as shared mobility. The use of AVs as privately-owned cars could create several concerns and potential problems if added to the current car park. Privately owned AVs could initiate long car trips where people had previously used public transport because of frustration, boredom, and fatigue of driving for long hours. They could increase vehicle kilometer travel (VKT) as they could provide access to people who previously relied on the public transport, walking, and cycling due to inability to drive personal vehicles. They could also invite more car travel in city centers where previously was avoided due to travel cost and unavailability of parking. (KPMG, 2016)

On the other hand, AVs functioning as shared mobility could reduce ownership of private vehicles which could lead to less number of cars. They could drastically improve mobility for people that do not have cars. They could also free more road space and parking areas. (KPMG, 2016) Different countries and continents have different approaches to the development of AVs. The European Intelligent Transport Systems (ITS) and the Norwegian ITS departments are working on the utilizing Autonomous vehicles as a Connected Cooperated and Automated Mobility (CCAM) system. For this reason, the thesis will investigate AVs as shared mobility.

The Selection AVs Functionality and Alternatives for the Thesis:

The National Transport Plan (NTP) and the urban growth agreement (Byvekstavtale) explicitly mandates on mobility in future developments be taken by walking, cycling, and public transport, and wants zero growth of person traffic. To comply with the NTP and meet public policy goals of creating a livable city, AVs need to function as shared mobility. For this reason, the thesis sets the limits for the research to the investigation of AVs as shared mobility.

Shared-Autonomous Vehicles (SAVs) could reduce car ownership and creates conditions that reduce the number of cars. SAVs can increase practical use of the vehicle and give improved mobility for people that do not own or drive a car. These are two alternatives in which the use of SAVs is possible. SAVs could function as shared mobility providers computing with the traditional public transport or as an integral part of the traditional public transport.

Alternative One- As a Mobility Mode Competing with the Traditional Public Transport:

This alternative uses SAVs as shared mobility providers which competes with the traditional public transport. “Traditional public transport,” means buses, trains, tram, cycling, and walking. The alternative could decrease the need for parking. It could also offer better access to public transport, and it could improve mobility for people with restricted access to the use of private cars.

However, it could create an inefficient use of public transportation as it could replace buses and trains with small cars to transport many people. It would require many vehicles to manage the demand. Such demand could create situations that would increase the waiting time for people to get the desired service. Alternatively, it would require an increase in the number of AVs to manage the demand. Both scenarios would increase the vehicle kilometer traveled (VKT).

Alternative Two – As Integrated Part of The Traditional Public Transport:

Alternative two uses SAVs as part of the traditional public transport. They function as integrated part of the public transport system. Such measures provide considerable scale reduction in the need for parking and would return a large part of the road to the people. It would also supply high access to public transport and improve mobility that has restricted access to personally owned vehicles. This solution also reduces the VKT and provide efficient use of the public transportation.

This mobility alternative offers two sets of scenarios. It could provide mobility as demand-oriented with door to door service, and it could provide mobility on a scheduled timetable with fixed routes. Scenario one, (scheduled mobility on specific route), SAVs are to operate in specific routes with fixed schedules. Moreover, the existing buses could use the technology and function in the same mobility system but with the ability to give service to a large number of people.

Scenario two, (demand generated mobility), SAVs could function as a first/last mile feeder to the traditional public transport, or as mobility service to places with less dense population and to areas with limited access to public transportation. Both alternatives reduce the VKT and still provide adequate mobility to people.

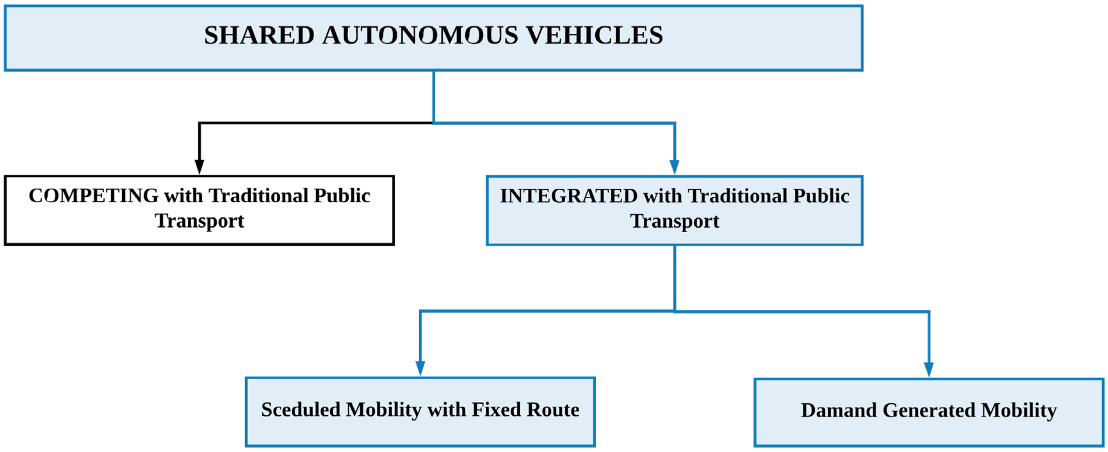

Figure 1.5 - Shared-Autonomous vehicles functionality scenarios.

Figure 1.4 shows the diagram for the scenarios that the thesis uses for the investigation. The thesis intends to continue the study with alternative two only (mobility as integrated part of the traditional public transport). The blue colored diagrams show the chosen alternative.

1.3. BUILDING FOR THE FUTURE

The current technological advancement is easily observable in our everyday life. We have transformed our communication appliances from cord-line connected telephone to a smartphone, new buildings labeled as smart buildings and our cities are working with a vision for a smart city. With the development of cities, there is always a demand for new road infrastructures to cope with the increased congestion problems. The constant building of new road infrastructures is creating a car dependency culture which also affects the transition of our mobility paradigm to sustainable mobility. However, as John Urry quoted the futurologist Buckminster Fuller famously saying that:

> ***"You never change anything by fighting the existing reality. To change something, build a new model that makes the existing model obsolete."***
>
> (Dennis & Urry, 2009)

In the time where the car dependency is very high, the automotive industry is working to introduce AVs. They are advocating that AVs would solve the safety and congestion problems of the society. (Waymo, 2017) The transport technologies are advancing very dramatically. History shows that the planning profession has not been effective in preparing for new transport technologies. While planning, we focus and react to the problems that arise rather than manage the future. As Ed Gillespie explained:

> ***"[…] Traditionally we have managed the urban transport mix, responding to the situation as we find it, we anticipate traffic trends and formulate policy to meet them. That is the past. The future is leadership, actively managing demand and changing our towns and cities to be cleaner, greener and more efficient to get around. […] We do not want to build the infrastructure of yesterday for tomorrow. So, we must lead the change we need, not just react to the things we think we want. […]"***
>
> (Gillespie, 2016)

The master thesis intends to investigate how SAVs could be integrated to aid in producing mobility that could outdated the existing car dependency culture. It also plans to investigate the impact of SAVs could have in transforming the transport infrastructure and the impact they could have on the urban land use to Stavanger City Center.

1.4. RESEARCH QUESTION

HOW COULD SHARED-AUTONOMOUS VEHICLES BE INTEGRATED TO HELP ACHIEVE SUSTAINABLE MOBILITY?

AND HOW COULD SHARED AUTONOMOUS VEHICLES IMPACT THE URBAN LAND USE AND MOBILITY IN STAVANGER CITY CENTER?

1.5. THE SCOPE OF THE MASTER THESIS

There is a tendency that we might not foresee the challenges that we could face in the continually changing world. AVs are one of such developments which could change mobility in general. There is uncertainty when exactly AVs would be out on the streets and how much impact they would impose on the cities. (Guerra, 2016) The thesis intends to investigate how to integrate SAVs to the existing transport infrastructure. It will also examine the requirements, barriers, and interventions to integrate AVs. The thesis further examines the role of SAVs in providing mobility in Stavanger city center and the impact they could have on the land use and transport infrastructure.

The impacts are theoretical potentials based on the hypothesis that: *"All uncertainties and regulatory and technological development regarding SAVS would be solved, and fully shared-automated vehicles could be implemented in the city center."*

The thesis will only consider AVs impact on personal transport in this study. AVs could also affect goods transport systems in the city center. However, the thesis will not examine them due to the limited time and resource.

CHAPTER –TWO

METHODOLOGY

Figure 2.1 - Methodology http://frontlinemillenniumschool.com/wp/educational-methodology/

2. CHAPTER TWO – METHODOLOGY

2.1. PHILOSOPHY OF SCIENCE: AMERICAN PRAGMATISM

Pragmatism is one of the philosophical contributions from America and was first developed by the four philosophical figures: John Dewey (1859-1952), Oliver Wendell Holmes (1841-1935), William James (1842-1910), and Charles Sanders Peirce (1839-1935). After the death of John Dewey, American pragmatism was on the decline, and analytical philosophy undertook it. However, American pragmatism was on the rise again after 1979 connecting the three contemporary American pragmatists: Richard Rorty, Richard Bernstein, and Richard Shusterman. (Barnes, 2007)

Trevor J. Barnes, a pragmatist British geographer, he was questioned on his philosophical views that pragmatism does not believe in anything. (Barnes, 2007) In A pragmatic view, the human action constitutes the essential part of everyday life. The experimental and creative characters are considered to be implicit while the experience and knowledge in the science achieved are explicit. (Gimmler, 2005)

There are different understandings among the different pragmatic thinkers, but they share a common philosophical interest. They look the world in an accurate phenomenal view rather than in an abstract. James illustrates that idea with the view that the meaning of reality is related to the conduct it is fitted to produce. The experience gained (the conduct) is the crucial factor to develop the meaning. In order the experience to have a meaning, the conduct must make a difference. Dewey also had a similar view that the practical meaning of any philosophical proposition is dependent on our practical experience. The concept must be applied in real life for the concept to have meaning. The true meaning of the concept develops when the concept is applied to the reality and makes a difference. Dewey argues that the origin of the concept does not constitutes true meaning, but its application which becomes the criterion of its value. (Ole B. Jensen a. D., 2016, s. 35)

The four philosophical figures also shared some common themes and emphasis. Some of the themes are mentioned below:

1. Anti – Foundationalism

Regarding Barnes, the most important shared believe of pragmatist was that ideas develop or appear randomly and experimentally in response to the needs and practices of people as they lived out their lives in a given place and time. Ideas do not exist in a timeless pre-existing perfect form, and that knowledge does not rest upon a solid foundation. Pragmatism was a philosophy of practical achievement where ideas were considered true when they allow us to get things done when they coped adequately with the world. (Barnes, 2007, s. 1544)

James defined truth to be whatever knowledge that proves itself to be good in the way of belief, while Dewey formulated it as truth was not fundamental in the world, nor was it a reflection of the world. In pragmatism, the truth was the knowledge that succeeded practically to meet our interests, values, and purposes. (Barnes, 2007, s. 1544)

2. Social Character

Barnes described knowledge in pragmatism as constitutively social since beliefs were collectively produced. They are responses to conditions and needs within our social environment. Knowledge had room for individuality and diversity. Methods, logic, problems, and techniques are all consequences of social agreements both implicit and explicit. (Barnes, 2007, s. 1545)

Barnes further illustrates that even though knowledge was social, it does not mean it is the truth. For knowledge to be the truth, it needs to be able to produce or succeed in their purpose. For pragmatists, if the knowledge produced does not make a difference, there would be no social agreement that it would not be regarded as truth. Peirce framed truth as knowledge which is destined to be agreed by all who investigated, and the object presented in producing the knowledge to be as real. (Barnes, 2007, s. 1545)

3. Radical Contingency

Darwin influenced the pragmatist thinking with the importance and role of a radical contingency, and the recognizability for the need to adapt to unpredictable situations. He stated that early pragmatists recognized humans need always to expect the unexpected. They believed that humans were astonished by chance, accident, and serendipity. Dewey used the notion “reflective intelligence,” meaning that truth is only a makeshift and that we should be willing to change our minds to accept it. We would have to refashion ideas for whenever new circumstances occur. Ideas should therefore also be treated as adaptable and pliable. (Barnes, 2007, s. 1545)

Peirce emphasized the power of chance and probability. He wrote that the whole process depends on chance. Everything that happens by chance could happen in again by chance. He also highlighted that significant changes could also occur by chance. The central implication of pragmatism is that we are living in a world of risk, which is created by our incapability to know about the future. Peirce further mentioned that pragmatists think that our beliefs about how the world will behave in the future are only guesses and these guesses are occasionally causing catastrophic consequences. He mentioned that pragmatists argue that contingency should be seen as an opportunity, which probably should not be avoided or seen as a separate part of a study by using words like necessity, inevitability, and certainty. (Barnes, 2007, s. 1546)

4. Fallibilism

Dewey mentioned that pragmatism necessitates to continual experimentation to deal with radical contingency, and also to find means for improvement and not every experiment would be successful. He said for it to be successful it needs openness, a willingness to listen, and democracy of hope. He further highlighted that in pragmatism, democracy and free speech are needed to allow people to express themselves, which maximizes the chance of experimentation. Holmes stated that the more individual variations in ideas there is, the higher the chance that we get the idea we need. (Barnes, 2007, s. 1546)

5. Pluralism

According to pragmatists, there is nothing that ensures final coherence, which means it cannot be expected that all ideas should cohere. James and Dewey were critical towards Hegel's notion of "final reconciliation" that for them the notion was wrong as James put it, that nothing dominates over everything and nothing includes everything. So, Dewey and James offered the concept of pluralism, which instead of difference, otherness, opposition, and contradictions been reconciled, should be put side by side, compared and made to challenge in their adjacency. (Barnes, 2007, s. 1547)

Pluralism means as Oscar Wilde described it, "Truth is rarely pure, and never simple" (Barnes, 2007, s. 1547). The world is contingent, messy and complex. Pragmatism believes in and insists for the validity of different purposes and different contexts. These can be reported from different points of views when capturing and reporting the world. The world is made of independent things that all relate to each other, but the relation differs from what angle you choose to look. It is plural, and it is connected in many ways at the same time. (Barnes, 2007, s. 1546)

2.1.1. PRAGMATISM REVIVED

According to Rorty, there are no foundational bases for proclaiming the truth. A timeless set of rules or a universal form of logic could not assure the philosophical similarity between the world and our ideas of the world. Knowledge is a matter of conversations about social practices. (Barnes, 2007, s. 1549)

Rorty had the second argument in his revival of pragmatism that philosophy should move towards various approaches such as hermeneutics, edification (which means the moral or intellectual instruction or improvement of someone), kibitzing (which means allowing informal chats, and conversation). He also argues that there are no foundational epistemologies. The meaning of knowledge becomes the product of interpretation, a consequence of different assumptions, background conditions, and practices. (Barnes, 2007, s. 1549)

2.1.2. PRAGMATISM IN THE RESEARCH

Pragmatism is well connected to practice and situations in everyday life, and the word pragma means 'behavior' (Ole B. Jensen a. D., 2016). Kilpinen said that in a pragmatic world, the action comes ahead of knowing. He said that the subject must set up a stable relationship to his or her world, and the experience (subject's action) creates the stable relationships.(Ole B. Jensen a. D., 2016, s. 36)

The research question relates to both practice and everyday life situations. The increase in motorized vehicle dependency and fast developing technological spectrum on the auto industry tend to disrupt the transport sector. For most people, our daily life is incorporated on the use of a motorized vehicle. Investigating how AVs could change the transport system requires AVs to be implemented which corresponds to the action before knowing.

Using a pragmatic approach to investigate the research question “How could SAVs be integrated to help achieve sustainable mobility? And how could it impact the urban land use and mobility in Stavanger City Center?” helps to investigate the potential of AVs role in the road to sustainable development and the possibility of shaping the urban form and ways of living. The introduction of AVs in the current mobility paradigm requires a complete change in the practices and planning paradigm. To investigate the conduct of the shift in paradigm as well as the practice would require the use of different methods. In the thesis, pragmatism is viewed as the best philosophical background to examine the research question. It also allows the freedom to choose different methods, techniques and research procedures that best suit the topic of investigation (Creswell, J.W., 2007).

2.2. RESEARCH STRATEGY

The master thesis used a pragmatic research philosophy which allowed using different methods to answer the research question. It was using a pragmatic approach as the approach states on achieving the best result by using a method that best suits to the desired investigation. (Creswell, 2007, s. 22) The research had divided the inquiry into two sections.

First, the thesis investigated how SAVs could be integrated to aid achieve sustainable mobility. In doing so, it examined the general vision and time-frame with the potential to implement such technology in Norway as well as internationally. Moreover, it researched the status and requirements needed both as the technological development of the vehicle and the infrastructure. Further, it studied the barriers, and interventions and strategies to integrate those vehicles. Secondly, it studied the possible impact SAVs could impose in the city center of Stavanger. It investigated the changes that could come in parking areas, transport infrastructure and the attractiveness of the city. To investigate the effect, it had used the interventions and strategies as a basis to presume the possible changes.

Like any paradigm shift, mobility planning would need a vision of how our city should be or should function. The thesis took into consideration the goals and aims of the Norwegian National Transport Plan and the Norwegian urban growth agreement. Further, the thesis had used theories such as urban sustainability and the potential role in providing sustainable mobility. Moreover, it revised theories about the impact of SAVs on land use and transport infrastructure management.

The thesis used documents such as Stavanger city plan and Stavanger city center section plan, strategies, web pages, maps and figures, and interviews. To analyze the data’s, it applied methods such as document analysis, sense of place, 8 to 80, and visual ethnography. The thesis collected primary and secondary data, where it used a mixed-use of data form, in which the data was analyzed qualitatively as well as quantitatively.

2.3. DATA COLLECTION AND ANALYSIS

This section introduces the different data collection methods and explains why and how they are relevant answering the research question. The thesis gathered primary and secondary data both qualitatively and quantitatively. The primary data are gathered as semi-structured interviews, visual ethnography while the secondary data collected data like regulation documents, web pages, and Strategies. The research used different sources for obtaining the data needed as the investigation progressed.

2.3.1. REGULATION DOCUMENTS AND PLAN DOCUMENTS

The thesis revised the Stavanger city plans, Stavanger city center section plan and areal analysis of Stavanger city center. The reasons for choosing such documents for this kind of research is to scope the degree of impact with regard the existing situation as well as the potential changes that could impact the city of the near plans. Other reasons are that the city is undergoing a significant transformation in the transport infrastructure and they also intend to redevelop the waterfront.

Analysis

The thesis has used document analysis to investigate those documents. It analyzed the documents to help understand the plans to the municipality and develop a comprehensive view on the city center of Stavanger municipality.

2.3.2. SEMI-STRUCTURED INTERVIEW

The thesis has chosen ten interviewees who are experts in their fields. Every interviewee has a significant role in the development of ITS technologies and autonomous vehicles. I have sent all the interviewees interview guide beforehand except Mr. Solvik Olsen. The interviews were all conducted with face to face interview on skype or in person except Mr. Madland, who choose to replay the interview guide in writing. The thesis has also included one interviewee from Denmark Mr. Scharfe to show the situations with regard the development of AVs internationally also. The interviewees are listed below:

INTERVIEWEES

1. **KETIL SOLVIK OLSEN** – is the Minister of Transport in Norway since 2013. He is actively working on promoting Norway to be at the forefront of ITS technologies and autonomous driving and autonomation. The interview was held in an informal interview on the 15th of March 2018.

2. **TROND HOVLAND** – is a chemist from the University of Bergen. And he been working with the public road administration 18 years before starting in ITS Norway. And he been working in ITS Norway for the past 9 years. He is the managing director of ITS Norway. And he been working on the impact of autonomous driving and mobility as a service on cities. And his main role is to bring the parties that could be impacted by the development and prepare projects to follow the discussions. And the interview was conducted on 1st of March 2018.

3. **ØYSTEIN HERLAND** – is an electronic engineer with specialization on economic and law. He is the managing director of Volvo Norway for the last 20 years. And he is a board member in Hertz-First Rent a Car Norway and Bilia Oy Ab in Finland, and the chairman for Opplysningsrådet for Veitrafikk As. And The interview was held on the 19th of March 2018.

4. **PH.D. HENRIK SCHARFE** – is M.A and Ph.D. on human-centered informatics and information science. He is a former professor at Aalborg University and founder of the center for computer-mediated epistemology and co-founder of Aalborg U robotics. He is the founder and CEO of Foundation Autonomous. He is known for the Hiroshi Ishiguro-inspired and Kokoro-built robot Geminoid-DK. Moreover, the time magazine had listed him as one of the top 100 most influential people in the world in 2012. He is an advisor to the government of Denmark on robot matters. (Scharfe, Henrik Scharfe, N/A) Now he is working in testing Autonomous vehicles on the municipality of Vesthimmelsland in Denmark. The interview was conducted on 5th of October 2017.

5. **OLAV MADLAND** – has an Honors degree within information technology, statistics and administration from the University of Bergen (1989), followed by a series of business management courses from Europe's prestigious and leading business school INSEAD (1999), in Paris, France. And he has mix of management roles within the telecom, banking and finance sectors, specifically issuing of credit cards, acquisition and settlement of transactions. And he introduced completely self-driving vehicles to Norway 2016 and has performed 20 demonstrations at different places in Norway. The interview was done as in a written format. And the interview included an article in which he wrote as a supplementary answer to the interview questions.

6. **ANDERS GODAL HOLT** – is the leader for the department of the transport technologies with the Norwegian Public Road Authority. And he has a role with the development of ITS and future transport mobility solutions within the NPRA. The interview was conducted on 9th of March 2018.

7. **LINN TERESE LOHNE MARKEN** – is the general manager of Forus PRT. Forus PRT has the responsibility of testing autonomous shuttle buses in Stavanger with co-ordination of Kolumbus and Forus Næringspark. The interview was done on the 6th of April 2018.

8. **GOTTFRIED HEINZERLING** – is traffic and urban planner and he has worked as the head of the transport department in Rogaland county for the past five and half years. He also was a researcher at IRIS before. His department has responsibility for almost all the major roads in Rogaland county. The interview was held on the 21st of March 2018.

9. **ELLEN F. THORESEN** – is civil engineer from NTNU in Trondheim with specialization in city and regional planning. She is the leader for department of overall plan in section for city and urban development for Stavanger Municipality. The interview was conducted on 11th of April 2018.

10. **OLIVER HUSØY** – is a civil engineer from NTNU in Trondheim and has been working for three years with the Norwegian parliament for the transportation committee with transportation policy and now is working for Standard Norway as head of market development in the transportation sector. And his role in Standard Norway is to investigate and find the needs for standardization and start the standardizing projects. The interview was conducted on 16th of April 2018.

11. **ITS NORWAY SEMINAR – CITIES IN FOCUS** - The seminar was held on the theme "Cities in Focus" in which questions regarding how technological opportunities and climate regulations could change our cities. And the seminar had presented topics that answer how we are preparing to handle new development, how architects and governments think and how we could standardize the new development to provide easy usage and to encourage innovative development. And the seminar was held in Oslo on the 14th of March 2018.

12. **ITS NORWAY CONFERENCE** – 2018 yearly ITS conference - was held in Oslo on March 15, 2018. And the conference had people presenting different ideas, products and regulation producers. The conference had topics such as accelerating mobility as a service concept, how C-ITS could be users in traffic regulating, and the year of multi-modality (the Europeans approach to turn mobility to multimodal mobility). The seminar also held panel discussions on topics how self-driving vehicles and autonomation could lead to a change in the transport sector and how we could promote Norway in ITS industry.

13. **BREAKFAST SEMINAR – GRØNNBY** – how will we travel in 10 years' time? - Grønnby and Kolumbus held the seminar and conducted with the theme that mobility is changing and will affect how we travel in the future. The workshop had different people presenting on the topics of how we will move in 10 to 20 years and what will be the consequence and how that will affect land use, resource use, and security. The seminar was conducted on the 21st of March 2018.

Analysis

The thesis has used the interviews and the seminars as a base for knowledge building to understand the matter and status of AVs within Norway. Further, they had shed light on the different aspects of the technology development and their challenges nationally and internationally. The thesis further analyzed the interviews for the interventions and strategies for the implementation of SAVs.

2.3.3. VISUAL ETHNOGRAPHY

The thesis has used the visual ethnography because it provides a useful approach to analyze the current situation within Stavanger city center. As Pink described images might inspire conversations and *"walking and photographing enables us to attend to elements of the ways that people experience and give meanings to their environments, and in this sense also enables a focus on the sensoriality of place"* (Pink, 2013, p. 81).

Visual ethnography in this thesis to widen the understanding of the circumstances with the investigated areas and discussions about the findings. Furthermore, the visual ethnography is used to develop a "Sense of The Place" to describe the existing situations.

2.3.4. GEODATA

The maps developed are made from SOSI file gained from the University of Stavanger. The maps are used to show the situations with traffic management and accessibility in Stavanger City center. Some of the statistics with number accidents, average daily traffic maps, and type of roads were collected from vegkart.no.

2.3.5. WEB-PAGES

The thesis used the web-page of Stavanger Municipality as a source for data collection, where the "Municipal plans and section plan of Stavanger city center plan" were collected. And I have used many more web pages that show the development of AVs.

2.4. VALIDITY

The thesis has chosen pragmatic research questions in identifying potential impact areas of the technological development of SAVs. It has used a pragmatic approach to investigate the questions. The pragmatic approach enabled the use of different methods that suits to investigate and solve the different aspects of the research questions.

The thesis used different methods to gather data. It selected people for interview who are key figures on the development of AVs and had to some extent a prominent role in the integration of SAVs in Norway. Interviewing those people allowed to collect genuine information to the current development of AVs. Moreover, the interviews were treated as knowledge building to the analysis of the potential impact of Stavanger city center and the integration of SAVs.

The thesis sent interview guide to almost all interviewees in advance ranging from 1 to 2 weeks. It allowed the interviewees to see the questions and prepare. As the technological development of AVs or SAVs is new, sending the interview guide aided that the questions were answered and understood in depth. The interviewees highlighted that there is limited knowledge of the vehicles and their development. The constant developing character of the technology affected to what degree of certainty do the interviewees answer the questions.

One of the challenges of the thesis was that there are no prior studies which have done the same study to the theme. To find relevant studies and literature was challenging, which also made the structuring of the thesis to answer the research questions difficult.

At the start of the semester, the thesis was structured as a case study of two cities, Stavanger municipality, and Kongsberg municipality. However, lack of enough participants from Kongsberg municipality forced the thesis to have the new structure and only focus on Stavanger city center.

One thing that could affect the findings of this research is the lack of in-depth knowledge on the research method and interview mechanisms, the lack of relevant literature and study on the AVs, and most of all lack of knowledge in analyzing something which is not applied in real time in the real world.

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CHAPTER –THREE

THEORIES

SHARED AUTONOMOUS VEHICLE ROLE IN URBAN SUSTAINABILITY

Figure 3.1 - Shared Autonomous Vehicle http://www.wemontreal.com/na-ulicax-monrealya-poy-avilis-mini-avtobusy-bez-voditelya/

3. CHAPTER THREE – THEORIES – SHARED AUTONOMOUS VEHICLES ROLE IN URBAN SUSTAINABILITY

3.1. A MEANS TO SUSTAINABLE MOBILITY

The meaning of sustainable development or sustainability is a diversely interpreted and applied concept. Most of the definitions relate to the Brundtland report from 1987 which states that sustainable development is *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs."* (Brundtland, 1987, s. 37) Sustainable development covers a broad aspects of the human activity, and includes economic development, community development, and ecological development. (Newman & Kenworthy, 1999, s. 4) And those development aspects also depend on the urban planning. As Wheeler explained urban planning addresses a vast range of disciplines such as land use, urban design, transportation, environmental planning, resource use, environmental justice, local economic development, architecture and building construction. Exploring those different dimensions of urban planning requires understanding of how those topics relate to each other. Understanding those links is a key to achieving a sustainable urban development. (Wheeler & Beatley, 2009, s. 83)

Transportation is a discipline that could alter the outcomes of the other disciplines of urban planning. Transport plays a major role in the society economically, socially, and environmentally. Current situations are dictating the need to transform the transport system to sustainable mobility. Sustainable mobility is defined by the world business council for sustainable development as part of Mobility project 2030 as:

> ***"[...] Mobility that meets the needs of society to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological requirements today or in the future."***

(Williams, 2007)

To integrate a new transport system requires a shift in mobility paradigm. David Banister mentions the need for the use of technological changes, regulating the transport and combine land use development to achieve sustainable mobility. (Banister, 2008) Nunen, Huijbrets, and Rietveld emphasized that the transition in a new transport system is not a short-term situation. Changes always take one generation or more to materialize the effect and impact completely. (Nunen, Huijbregts, & Rietveld, 2011) However, it is necessary to see every technological development in the transport system on whether they would support sustainable mobility. It is essential to explore the relationship between the environmental, social and economic aspects of the transport system to understand their role.

3.1.1. ENVIRONMENT BENEFITS AND CHALLENGES

Morelli John described that out of the three pillars of sustainability; the environment is the only one that can function without depending on society or economic development. However, the social-economic development of our existence is dependent on having a sustainable environment. (Morelli, 2011) Environmental Sustainability is defined as

> ***"Meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them."***

(Morelli, 2011, p. 6)

To understand the environmental advantages of aiming to transform the current mobility practices to sustainable mobility needs awareness to the problems created by the road traffic transport system. The demand for constant economic growth and the need to continually move is creating a potential threat to the sustainable environment. Climate change is one of the leading challenges facing our generation and the future we foresee. One of the primary sources is the choices of transport mode we make for our everyday movement. There is an intensified demand for transporting goods and passengers with the constant growth in economic and technological development. Today, transportation contributes approximately 30% of the global warming of the planet. (RUSKO & KOTOVICOVÁ, 2016)

The principal air pollutants emissions: carbon monoxide, oxides of nitrogen and unburnt hydrocarbons are dependent on the vehicles technological improvement. Particulate matter is reliant on driving style, driving conditions and ambient temperature and mostly the increase in the number of cars. (Vehicle Certification Agency, 2018) In 2013, there were around 1700 people died with health problems caused by smog. The increase in particulate matter and oxides of nitrogen creates more health-related problems in Norway. (Naturvernforbundet, N/A)

Besides, about 80% of the noise pollution in Norway is caused by road transport vehicles. (Staten Vegvesen, 2017) The noise pollution is as a result of the increase in the number of cars, and they have access everywhere, even where people live. There were around 2.6 million private cars registered in 2016 for a population of 5.3 million living in Norway. The car ownership, when related to the number people, is approximately two persons for each vehicle. (Statistics Norway (d), 2017) Since 1992, the Norwegian parliament has not updated the noise requirements for cars, and the automotive industry has not worked to limit noise problems from vehicles. (Norsk Forening mot støy, 2013)

Autonomous vehicles advocates tend to exaggerate the savings and benefits of autonomous vehicles have on the society and the economy. Also, they predict on autonomous vehicles ability to increase the convenience and safety, reduce congestion, and fuel consumption and pollution emissions. There is a tendency for such benefits, but it is not confirmed aspect. The benefits to be utilized would require the acceptance and use of autonomous vehicles by all the public. (Litman, 2017)

Autonomous cars would need a significant advancement on the technological aspect to function with safe and beneficial manner on the streets. They would require a significant technological development in sensing the physical world and interpreting the gathered data to understand the physical world. The challenges of Autonomous driving simplify on level 4 and level 5. Level 5 is expected to drive on all types of environment. The environment imposes a significant challenge regarding the safe driving and acceptance of the public to use Autonomous vehicles in public.

The environmental benefits are claimed to profit from a compact urban form. It results in the reduction of air pollutant emissions from vehicles and creates a safe and comfortable distance for walking and biking. A compact urban form provides a means for open green space which also benefits society for a better quality of life. (Jenks & Jones, 2010)

3.1.2. SOCIAL REQUIREMENTS AND CONCERNS

This section discusses the relationship of the transport system to the society. Nunen, Huijbregts, and Rietveld described the importance of transport for society to satisfy the demand for social contact, various activities, and transportation of goods. They emphasized the society's need for those different demands to be affordable, reliable, non-delayed, convenient, comfortable, accompanied by high-level service, and have practical value. (Nunen, Huijbregts, & Rietveld, 2011)

The need for a social contact results for a need to travel and creating a mechanism through which develops mobility cultures. Hickman, Schwanen, and Banister meant that people come into contact with norms and aspirations with the choices they make in the travel, whether it counts for bad or appropriate behavior. They stressed that the social norms are that dictate the choices on what kind of transport mode to take. Social norms that favor car use makes people not to use the public transport, walking and biking even though they have better access to use them. On the other hand, social norms that favor non-car travel makes the sustainable mobility modes to have a positive impact on the society and creates a healthy way of lifestyle. They mentioned that the car is as indispensable to some parenting cultures where parents deal with the need to be on different places on short time span due to work, family and the needs of their children's activities and personal needs. They also explained that people consider the car as it provides specific traffic safety and privacy issues. The travel habit of the society demands a transformation of the social norm and mobility cultures to achieve sustainable mobility. (Hickman, Schwanen, & Banister, 2010)

Williams described that people demand mobility that meets the travel needs of the population. He emphasized that people that always travel value travel time and expects it to be reliable. They also expect the cost of transport to be affordable. They want their experience to be as comfortable as possible. Most of all, they value their safety and security. He stressed that in car-dependent society, mobility must ensure the needs of all users. People who cannot travel by car because of age, cost or ability needs to have access to adequate mobility. (Williams, 2007) Nunen, Huijbregts, and Rietveld explained that those certain groups in the society have fewer opportunities to take part in social interactions. Part of this exclusion could be due to lack of access to transport, where public transport is poor. They mentioned that the social exclusion is among the main reasons for public transport subsidies. (Nunen, Huijbregts, & Rietveld, 2011)

Another dimension of society's demand on transport is traffic safety. The trend and intentions at this moment in many countries are to make the transport system safe with goal of zero casualties even though the traffic volume continues to grow. Technological and economic development have also improved the social sustainability providing an improved quality and safer transport system. (Nunen, Huijbregts, & Rietveld, 2011)

Autonomous vehicles are supposed to reduce traffic accidents, but they will sometimes have to choose between two evils such as sacrificing themselves and the passenger to save the pedestrian or killing the pedestrian to save the occupants of the autonomous vehicle. The challenge for the manufacturers and the government is that solving this social dilemma. The concept of autonomous vehicles deciding the outcome of two evils plays a prominent role in the acceptance of autonomous vehicle. On the survey done about the social dilemma of autonomous vehicles shows that people do not want to buy a vehicle that sacrifices them for the greater good, even though they said the vehicle should sacrifice occupants for the greater good. (Jean-François, Azim, & Iyad, 2016) However, Mr. Henrik said that "we do not expect drivers to choose the fate of others, so why do we expect machines to do so." (Scharfe, 2017)

Hence, the German federal government adopts a set of guidelines for self-driving cars ***"[...] To prioritize the value and equality of human life over damage to property or animals. [...]***" (Gershgorn, 2017) The guidelines state that autonomous vehicles must do the least amount harm in situations where hitting a human is unavoidable and that it cannot discriminate based on age, gender, race, disability or any other observable factors. (Gershgorn, 2017)

The different challenges require a thorough understanding of autonomous vehicles by all parties for the transport mode to be useful for the public socially and economically. The challenges have different aspects where the problems require the guidance of federal government. There also requires an open mind for unintended consequences that could emerge. Autonomous vehicles would require for cities and town to investigate the cities with a new perspective how they could change the infrastructure and mobility planning.

The most and mainly debated part of the inconvenience of autonomous vehicles is the potential for vulnerability for security and privacy issues. Autonomous vehicles could be hacked and be used for illegal activities. Even more, they could be used for terrorist and unlawful activities such as delivering bombs. Autonomous vehicles could be vulnerable to information abuse and privacy issues concerning tracking systems and data sharing. (Litman, 2017)

Autonomous vehicles could affect the culture and health of the society. They could significantly influence people to be more comfortable to use them instead for walking or biking. People could also be more dependent on the autonomous vehicles for their everyday activities. There is a tendency to influence the culture of the society that the communities would be a car-dependent society. The cultural change could also structure our cities on the concept of autonomous dependency. (Litman, 2017)

Jenks and Jones described that urban form affects the social benefits of sustainable mobility, where higher density and mixed-use urban structure would lead to a better quality of life and social equity. (Jenks & Jones, 2010) All those aspects play a part on the demand, problems, and concerns with the social characteristics of sustainable mobility.

3.1.3. ECONOMIC VIABILITY

This section discusses the economic aspects of the transport system. Newman and Kenworthy mention that although transport priorities are significant factors in shaping the urban form, it needs a commitment of economic resources to build the infrastructure. (Newman & Kenworthy, 1999) The economic aspects of the transport include infrastructure building, managing the traffic, and building parking area, congestion pricing, taxation on vehicles, and least but not last health-related economic advantages.

The use of vehicles has internal costs to the user which includes costs that the user pays directly at the time of travel or journey and indirectly as vehicle payments, taxes, and insurance. Car users associate those cost only to their journey. They get the notion that the use of private cars is cheap. Private vehicles induce the most external costs where the society pays it through taxes for each person transported. Whereas, the public transport users pay part of the internal costs and the authorities subsidize the rest. Mobility based on the sustainable mobility where the use of the public transport, walking, and biking are the social norm of the society reduces the external costs. (Universitat Autònoma de Barcelona., 2018)

Ian Shergold mentioned that the environmental benefits of sustainable mobility also benefit society economically. Creating environmental zones and reducing the speed limit improve road safety, which reduces costs of accidents, and improves the health of the society, which also reduces the death from respiratory problems due to pollution. (Shergold, 2016)

Shergold described the cost of managing the traffic through road space re-allocation and congestion pricing also provides economic as well as social and environmental benefits. He further mentioned that structures, where the general traffic lane is re-allocated to give additional priority to sustainable mobility modes, reduce traffic volumes, improves travel time, increase the use of non-car modes and reduce casualty numbers. He emphasized the attractiveness of the destination influences the economic benefits of congestion charges, whether it is employment, trade or leisure to attract enough people to the congestion zones. He highlighted that road users believe time savings to be the main benefit, but there is a large variation regarding the value of travel time savings to the congestion charges. On the other hand, introducing congestion charges without introducing an alternative mode of transport to the car has a low probability of generating substantial benefits. (Shergold, 2016)

Todd Litman described that some of the potential benefits of autonomous vehicles are that they would reduce driving stress allowing motorists to work and rest while traveling. There is a possibility to increase mobility for non-drivers or people with a limited function. They can increase the safety of road users by reducing accidents due to human errors which would reduce crash costs and insurance premiums. He further mentioned that AVs could initiate platooning which could increase road capacity. The livability in cities could increase because of the potential AVs reducing congestion. They could aid in narrowing lanes and intersections which could reduce roadways building and maintenance costs. (Litman, 2017)

Litman highlighted that Autonomous Vehicles have a potential to increase fuel efficiency and reduce pollution. They could reduce vehicle ownership by introducing a car sharing which would provide savings. They could reduce cost by creating a more efficient parking use. Additionally, he stressed that Autonomous Vehicles would reduce driver costs for taxis and commercial transports like public transport, which would help to introduce a demand-based transport service to increase the mobility of the public without affecting the cost of transport. (Litman, 2017)

Litman also mentioned that autonomous vehicles also have some inconveniences socially and economically. Some of the inconveniences are that autonomous vehicles would require extra costs as the vehicles would require additional vehicle equipment, services and maintenance, and possibly road infrastructures. Moreover, he stressed that AVs would require extra maintenance as they are to be driven autonomously. Autonomous vehicles may introduce unintended risk with system failure or be less safe under certain conditions. (Litman, 2017)

Autonomous vehicles tend to increase vehicle kilometer traveled (VKT) and increase costs due to crashes due to V2V or V2I communication problems. Autonomous vehicles have a big impact on the other sustainable mobility modes such as walking and biking by misplacing planning emphasis. They would also create social equity concerns for people which could not afford such vehicles. They tend to reduce employment and business activity, where jobs in the transport sector would be affected mainly. (Litman, 2017)

One of the benefits of autonomous vehicles is that it would give access to different non-drivers mobility solution. The main challenge of autonomous vehicles is the cost of the vehicle. Although the benefits of autonomous vehicles are clear, the inability to afford such vehicle could be an obstacle for the people who need it most. (Rand Corporation, 2014)

Providing a new mode that functions as comfortable as the car, but people use it as public transport mode would benefit socially, economically and the environment we live. The economic benefits of sustainable mobility dictate the different costs related to the social norms of transport choices. However, the three pillars of the sustainability must function within the urban form. Moreover, urban form determines how those pillars would benefit society.

3.2. AUTONOMOUS VEHICLES IMPACT IN URBAN LAND USE AND TRANSPORT INFRASTRUCTURE MANAGEMENT

This section discusses the elements of urban form. Those elements are identified based on their role in describing the transformation of the city with the implementation of sustainable mobility. Although the urban form affiliates with physical and non-physical features of the city. (Jenks & Jones, 2010, pp. 21-32) This research is considering the effects of autonomous vehicles on providing a sustainable urban development and the changes that would be on land use and transport infrastructure management. Those characteristics are part of the elements of the physical dimensions of the urban form. The effect that imposes on those elements is also reflected in the layout of the city, what kind of housing and building types we build and the densification of the urban area. Thus, land use and transport infrastructure management also dictate how we move or which choices we make in our everyday mobility.

3.2.1. MANAGING TRANSPORT INFRASTRUCTURES

This section will discuss the criteria for defining the transport infrastructure. This thesis is considering transport infrastructure as infrastructure and accessibility. “Infrastructure” refers to the quality of roads, sidewalks or bicycle lanes, tracks for traffic participants and digital infrastructure, while “accessibility” refers to the availability and opportunities of using a transport system to reach a particular destination within a city or a country.

Jenks and Jones associated accessibility with the ability to travel or reach a specific place, space, and building. It is dependent on factors of the people’s destination from their starting point or area, how public transport integrates into the area, and how people use the public transport. They further mentioned that different aspect of the accessibility cover access to service and activities within walking distance and having the means to get to a distant location. (Jenks & Jones, 2010)

Gössling described that the quality of the infrastructure for different traffic participants is dependent on city’s preference and most cities often favor individual motorized transport. (Gössling, 2016) Wheeler and Beatley further highlighted that the quality of the infrastructure dependents on the street dimensions, design speeds, and intersections. They described that minimizing street width, lowering speed limits, and designing roads and intersections to facilitate both vehicular and pedestrian movement is essential in the transition of the urban form to a more sustainable urban development. (Wheeler & Beatley, 2009)

Managing the transport infrastructure is vital to cities and touches many spheres of life. No town can function without its passengers and freight transport system. However, the choices of the transport mode have affected the daily lives of many and the quality of life.

The industrialized nation has craved to have fast improved mobility within their cities. They measured development by the superiority of their infrastructure and the use of automobiles as means of their improved urban mobility. However, they had not anticipated the consequence of the problems and rapid growth of demand in the use of cars within their urban life. As a result, the cars have caused a serious of environmental, social and aesthetic problems in cities. (Crawford, Carfree Cities, 2000) Starting as early as the 1920s, one of the main common problems in inner cities were traffic jams, and they created a dangerous encounter to pedestrians and bicyclists. And Le Corbusier summarized streets as “machine for traffic” and cities as “a factory for producing traffic.” (Morhayim, 2012)

Crawford describes problems the urban automobiles imposes in our cities. He describes that they kill the street life, damages the social fabric of the communities, and isolates people. Automobiles foster suburban sprawl, endangers other street users, blots the city’s beauty, disturbs people with its noise, causes air pollution, slaughters thousands every year, exacerbates global warming, wastes energy and natural resources and impoverish nations. However, our urban cities have a dilemma of choices whereas the challenges are enforcing to remove automobiles from the streets and the cities, while at the same time improving mobility and accessibility in finding a sustainable infrastructure. (Crawford, carfree cities, 2018)

Crawford recommends solutions which can help supplant the urban automobile. And he emphasizes that if and only if a better alternative is available, cities could remove automobiles from the streets. When lawmakers make decisions on such topics, people always question their political stand. They have to answer questions such that, what would happen to the city if cars are fully or partially limited access? Or does it affect or make social, economic and visual changes to the city? And most of all, would it be possible to have convenient mobility in the city? Therefore, none will enforce such decisions unless there is a better solution. (Crawford, Carfree Cities, 2000)

AV lobbiers and manufacturers are emphasizing that SAVs and redesigning personal mobility are means that could replace car dependency, reduce congestion, and traffic accidents. AVs have a potential to create new mobility concept and improve public transport. (Maurer, Gerdes, Lenz, & Winner, 2016) Crawford was critical of the ability public transport to replace personal mobility in his book car-free cities. He stressed the need for a pleasant experience while using public transport, and the need for effectiveness and time-saving. (Crawford, Carfree Cities, 2000)

Transport infrastructures management is not about the infrastructures and the vehicles only, but also about the cultural and social norms. The need for mobility with different means of transportation that dictates the norms of people’s preference. Maurer, Gerdes, Lenz, and Winner categorized people on the preference of transport modes they made into three. There are people with a distinct preference for private vehicles, people who prefer to travel economically viable mode such as combining public transport, walking, and cycling, and those that do not restrict themselves to a specific category who categorize themselves as multi-modal users. This concept aides on the rethinking of the transport system, creating a new modal system that incorporates all in one, Shared Autonomous Vehicles. (Maurer, Gerdes, Lenz, & Winner, 2016)

Managing transport infrastructures using AVs have created a possibility for car sharing system mobility and better end to end public transport system. (Maurer, Gerdes, Lenz, & Winner, 2016)Current development of AVs is an auspicious development that could facilitate Crawford's vision of partially or fully car-free cities. Possible changes to the transport infrastructure could only be possible by providing a change in the use of the streets from a car dependency to sustainable modes-oriented mobility. Change in infrastructure could only happen when we removed cars from our streets. (Crawford, carfree cities, 2018)

Infrastructure change dependents on managing the fleets that will replace the car. Managing fleets of SAVs requires how we see the future and the possible SAVs functionality within our cities that are car-sharing and hybridization of public transport. New mobility concepts that could manage those vehicles are dependent on how we want to live or how we want to move. According to Maurer, Gerdes, Lenz, and Winner, car-sharing could be managed in different modality scenarios, whether a station based car-sharing, flexible one-way car sharing or end to end car sharing. However, they described that the objectives of car-sharing vary depending on the perspectives of the parties involved. Political context and car manufacturers could have different objectives. They further explained that car-sharing also dependents on providing good public transport as a contingency plan for people on their everyday mobility. (Maurer, Gerdes, Lenz, & Winner, 2016)

Maurer, Gerdes, Lenz, and Winner highlighted that looking beyond the car-sharing mobility and redeveloping of public transport using SAVs could create a more flexible form of public transport. They further explained that SAVs could expand the public transport service options and individualization of the public transport to some extent. This modality of transport system generates a demand-driven service, where additional routes could supplement fixed routes according to customer requirements. They described that the temporary optimized routings could replace fixed timetable schedules. (Maurer, Gerdes, Lenz, & Winner, 2016)

SAVs deployment as public transport is incentives mostly driven by transport service providers, municipalities, and operators of facilities where slow-moving passenger vehicles are needed to provide transport within the urban areas. They are arranged to provide mobility for market introduction in limited areas as first and last mile solution. Maurer, Gerdes, Lenz, & Winner explained that the expectation of SAVs driving at low speed and limited geographical range could assist the urban street traffic and transport infrastructures within the urban area. They highlighted that those vehicles could also compete with the traditional taxis and could be affordable, comfortable, and innovative from the customer and operator's standpoint. Such features are thought to gain access to new business areas. They also mentioned that the reduced need for a driver in SAVs is one incentive that is anticipated to reduce labor cost and subsidies of public transport. Further which will reduce the cost of using such vehicles by the public. (Maurer, Gerdes, Lenz, & Winner, 2016)

The future is not guaranteed, and history of planning has shown that we could easily end up on the wrong side again. Managing the transport infrastructures is critical on how our future mobility is desired. SAVs have a huge potential to create a safe environment where streets could be designed with special attention to pedestrians and cyclists and regulate digitally speed limits in real time situations. And they could provide more accessible, convenient and affordable mobility for the entire city. With the necessary policies, they could transport more people with fewer vehicles. And, cities could manage space and land use better. (National Association of Cities Transport Officials, 2017)

Transport infrastructures are influenced by the layout of cities and vice versa. Traditionally city planners have been proposing the best possible physical layouts for the urban area. This physical layout involves certain combination of size, density, structures and built form, that are integrated to various urban functions. (Marshall, 2005) The connectedness and permeability of those urban layouts determine the nature and extent of the routes between and through spaces. This also influence on how the space is well used and how lively the area is. Further it allows the management of the transport infrastructure where access and movement of pedestrians, cyclists, and vehicles is attained. (Jenks & Jones, 2010)

3.2.2. LAND USE

This section will discuss the different elements of land use in the urban context. The term "Land Use" is used to describe the different functions of the location. Jenks and Jones characterized a functional urban area as an area that includes a residential area, industrial areas, retail area, office areas, infrastructures and other uses. The efficiency of a city and the potential sustainable urban form influencing the urban travel and the quality of life depend on the spatial pattern of the land use. (Jenks & Jones, 2010)

Jenks and Jones explained that land use pattern is market driven. They emphasized that it is a dynamic phenomenon rather a static incident. They further described the essential constituent of land use as the availability of a local urban context where there is a need for local neighborhood services and the requirements of the population's criteria for service and facilities. (Jenks & Jones, 2010)

Wheeler and Beatley rationalized that land use is dependent on the type of the orientation of the development. It could be transit-oriented development or automobile-oriented development. They highlighted that those orientations also dictate the pattern of growth and defining the growth axis and growth boundaries. They explained that developing the growth strategy dependents on providing a social diversity, environmental protection, and transit. It also has a potential to create livable communities that accommodate institutes, protects open spaces and memorable places. They emphasized that the need to place human scale at the core in planning and promote a variety of architectural domains and building types (Wheeler & Beatley, 2009)

AVs are expected to entail a new mobility paradigm where transport management and effects of reduced car dependency within the city would revolutionize the land use. Since SAVs and autonomous driving has not been a reality, effects of the urban development and urban structures are not observable. AVs has a potential to impose on the features of the city of tomorrow where infrastructures and cities could be powered with renewable energy source buildings and roads. The technological development accompanied with a behavioral change in the urban population could create a society with a greater desire for well-being and quality of life. Such movement could alter the way our cities are built, or land use is utilized. One of the primary impacts of AVs would be the change in parking areas within the city, attractiveness of the location and the change in space required to road structures.

A. Change in Parking Area

The possible effect expected in the urban structure from the use of SAVs is that the shift on parking areas needed for private vehicles at home and the destination. The change on parking area required for home parking is substantial. However, Maurer, Gerdes, Lenz, & Winner explained the degree of the effect could also change according to the settlement structures. In residential neighborhoods of single families where the parking areas are within the same plot, the changes could be moderate that people may sell their second car and still have a need for the parking area.

In areas of higher density, Maurer, Gerdes, Lenz, and Winner explained that there could be a complete change to the common parking area giving access to the SAVs and the area would be redeveloped or used for other purposes. They further mentioned that in case of the parking at a destination place, whether shopping, leisure, or workplaces, SAVs would reduce the need for parking in every station. The vehicles could be able to drop customers off at the desired place and be on the motion to the next customer. (Maurer, Gerdes, Lenz, & Winner, 2016)

Maurer, Gerdes, Lenz, and Winner highlighted SAVs ability to park by itself as an essential development for saving parking spaces. They explained that technological developments are making different aspects of mobility a reality and intensify each other's potential through compatibility. They exemplified that SAVs can be space efficient and increase parking density by removing the need for ramps and aisles and replace them with lift shafts. (Maurer, Gerdes, Lenz, & Winner, 2016) At the moment, the Norwegian regulations on parking for a personal vehicle is 20 m2 at a surface or parking buildings, and 10 m2 for private cars on a roadside with 3 m2 open area every second vehicle on the roadside. (Staten Vegvesen, n/a)

Maurer, Gerdes, Lenz, and Winner explained the further changes required in the urban space as the need for pick- up and drop-off areas or stations. They highlighted that there would be a need to remodel of the mobility hubs such as transfer stations between different forms of public transport. They further emphasized that the introduction of SAVs would require an extensive reshaping of the public transport system and the supporting infrastructures. They would demand changes to the terminals to further increase activities, shopping and service facilities. (Maurer, Gerdes, Lenz, & Winner, 2016)

B. Impact on Attractiveness of The Area

As Maurer, Gerdes, Lenz, and Winner explained the quality of life and the living environment influences more than the wish to be near their workplaces to people's choice where or how to live. The choices of living far away from their workplace promote too many people commuting to work and spending more time stack on road congestion. Also, people spend their time circling the place or city to find a place to park the vehicle. They clarified that the situation affects the attractiveness of the destination place or the city. (Maurer, Gerdes, Lenz, & Winner, 2016)

The use of SAVs could increase the attractiveness of the city center by reducing the use of personal vehicles. Streets could be redesigned to manage right of way and model streets based on people's activities. Spaces used for the cars could be developed for residents to interact and enjoy with neighbors and friend. Cities could rejuvenate areas acquired from roads for sidewalk cafe and other activities. (National Association of Cities Transport Officials, 2017)

C. Change in Road Structures

Streets are more favorable to vehicles, with much consideration put into what they require to maneuver them. The introduction of SAVs, firstly and foremost, changes the attention to the needs of the people and their activities. Planners could manage streets according to how people will enjoy their stay and their journey. (National Association of Cities Transport Officials, 2017)

One of the possible impacts is that Streets could be reduced in their width making crossings safer and not time-consuming. As SAVs would use a moderate speed seemingly a bicycle speed, interactions between different sustainable mobility mode users could be more efficient. The figure 3.2 shows how streets could be redeveloped to increase the livability of the city. Roads could be redesigned to have frequent crossings.

Chapin, Stevens, Crute, Crandall, Rokyta, and Washington explained that traffic today is managed with a focus to reduce conflict points at or near intersections and making the drive more efficient. They emphasized that in the era SAVs, traffic could be maintained in the way that would reduce bottleneck situations at intersections by accommodating pedestrian crossings lines. Crossings could be made more accessible by allowing mid-block crossings and the ability to cross directly to the desired destination. (Chapin, et al., 2016)

Further, we could redevelop streets to fit how we want to use the space. Spaces could be used by different vendors making streets livelier. Public seating areas, freight loading, green infrastructures, street markets, pick-up and drop-off areas, and transit stops could all be included making our streets more comfortable to people than to cars. (National Association of Cities Transport Officials, 2017)

The relationship between transport and land use is the critical component of creating livable areas. The growth of an area is dependent on what kind of transport orientation is preferred. Moreover, land use determines the density and livelihood of the city.

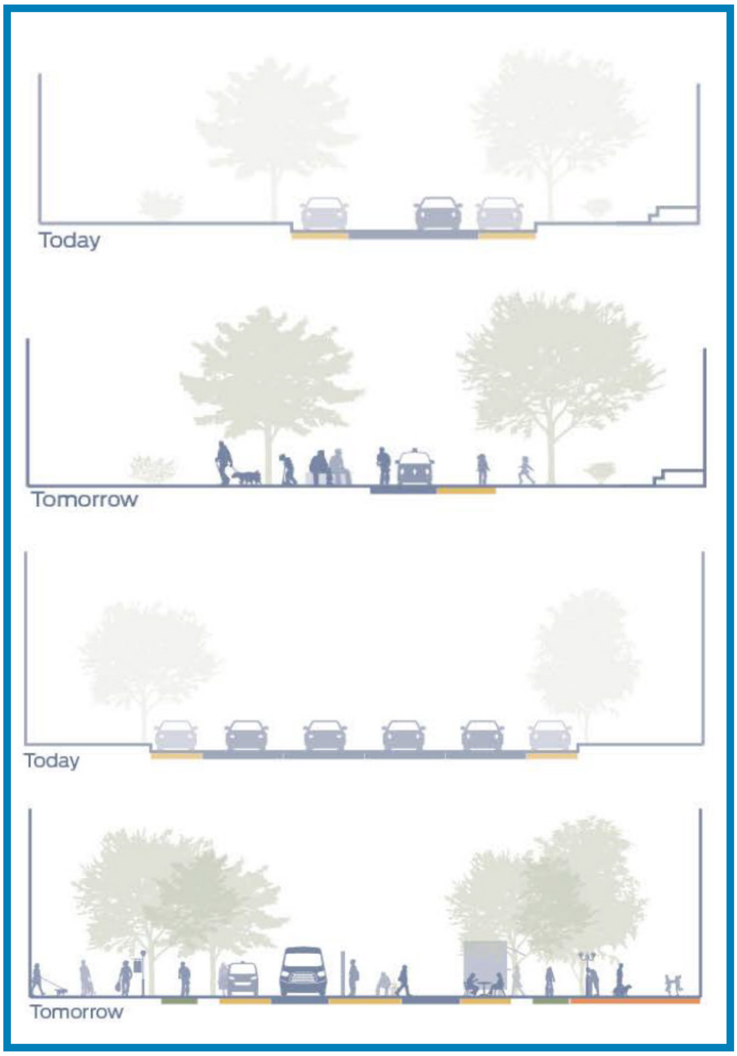

Figure 3.2 Possible changes to road structures. (National Association of Cities Transport Officials, 2017)

3.2.3. DENSITY

This section discusses the relationship of density on the urban form and its role in sustainable transport. It formulates the theoretical background for investigating the effect of transport system on the density of the city and its concentrations around the urban area.

Density is a complex concept with several inter-related dimensions. Jenks and Jones explained that density patterns closely links to transportation, land use and access to service. Consequently, they highlighted that it could provide objective measures of the number of people living in a given area, while it can also supply a subjective assessment of social interpretation dependent on the individual characteristics. (Jenks & Jones, 2010)

Jenks and Jones described that there are two ways of studying density. On the one hand, it can be the outcome of the competition between land uses within a given transport infrastructure and the accessibility associated with it. On the other hand, cities consider density as a policy goal in providing a means for the quality of urban life. They explained further that the quality of life also depends on the possibility and need for the service providers to serve a specific population size. Density has been a vital tool in measuring the sustainability of public transport infrastructure and other service providers. It also aides to feasibly allocate certain land uses for commercial and service in urban development and construction. (Jenks & Jones, 2010)

SAVs introduction provides possible changes to land use and transport infrastructures which in their part also affects the densification of the urban area. The characteristics of the urban form all dictate on the way we want to live. The way we live determines our regulations and policies. Regulations and policies also shape the future.

3.3. PLANNING POLICIES

In this section, the thesis reviews of the summary of the national policies, and international agreements. Planning policies are essential for every development especially on occasions which demands it. Moreover, SAVs are one of those developments that requires planning. They tend to disrupt the fabric of the urban development if not planned.

3.3.1. URBAN GROWTH AGREEMENT

The Norwegian government wishes for an environmentally friendly urban development to comply with the Norwegian climate policy (klimaforliket) and the Paris agreement. The urban growth agreement bases its contract on achieving a goal of zero growth in passenger traffic in cities. The future personal transport growth is to be planned with the prospect of being taken with public transport, cycling, and walking. The agreement consists of several measures and means such as; road pricing to finance the city-package (Bypakker), how to allocate road and rail resources, and area measures. The agreement rewards cities with funds and the scheme for state part-financed large collective projects. Besides, municipalities that sign the contract with the government are required to fund and take measures for their districts. (Kommunal - og moderniseringsdepartementet, 2017)

3.3.2. NATIONAL TRANSPORT PLAN

The National Transport Plan 2018–2029 is a vision aimed to achieve the overall goals for 2050 horizon, and it seeks to allocate resources to the transport sector for the next 12 years. And the goals are as follows:

> ***"A transport system that is safe enhances value creation and contributes to a low-carbon society."***

(Samferdselsdepartementet, 2016)

The NTP divided the main aims into three aspects which defines the overall objectives. They are mobility (better mobility for people and goods throughout the country), transport safety (reducing accidents under the Vision Zero), and climate and environment (reducing the climate emissions and adverse environmental impacts in line with the climate agreement and Paris Agreement). The summary of the programmed objectives of the NTP 2018-2029 is shown in the figure below. (Samferdselsdepartementet, 2016)

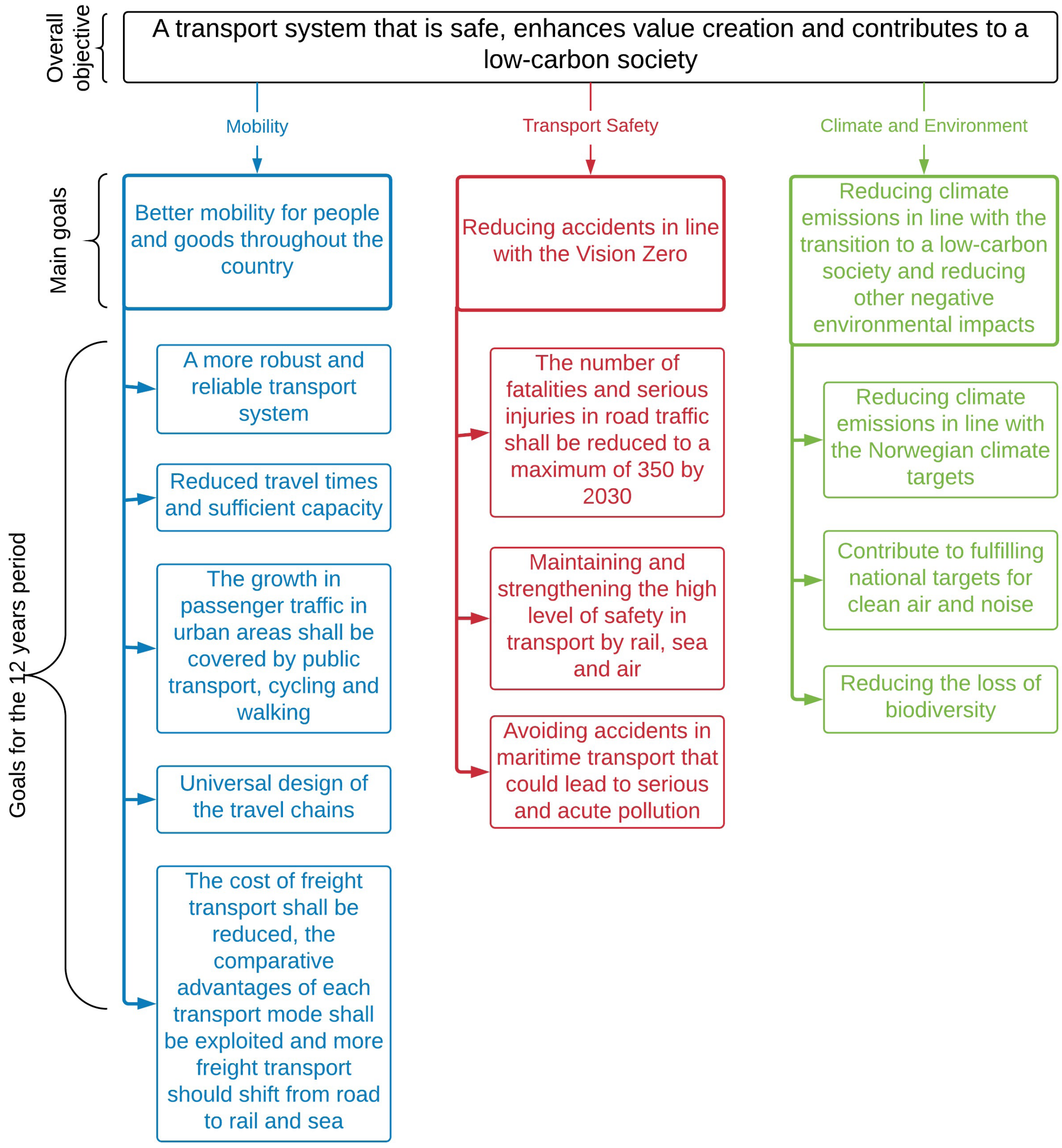

Figure 3.3 - A set of transport policy objectives (Samferdselsdepartementet, 2016)

3.4. RESEARCH DESIGN DIAGRAM

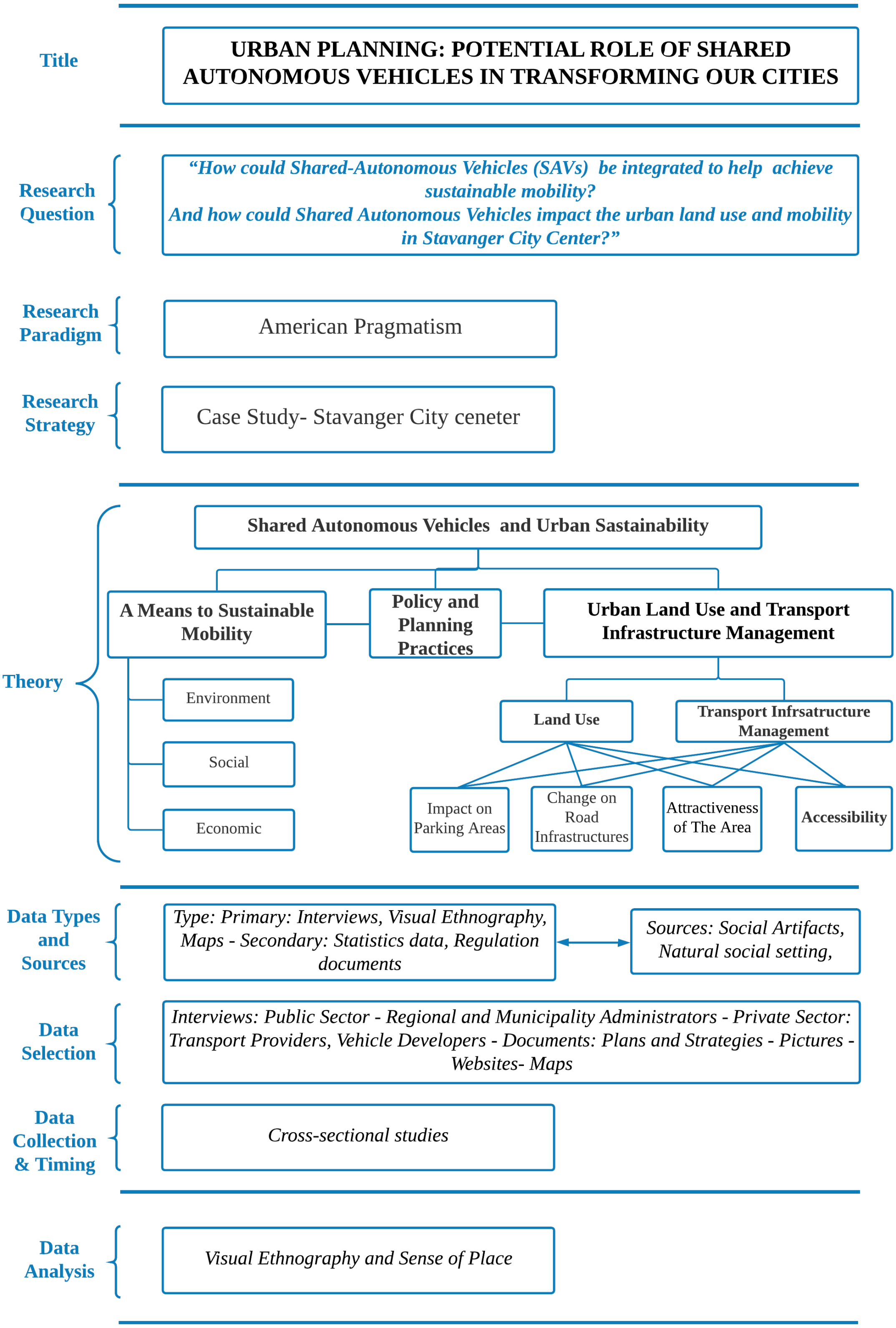

Figure 3.4 - Research Diagram (own figure)

CHAPTER FOUR

POSSIBLE APPROACH TO INTEGRATE SHARED AUTONOMOUS VEHICLES

Figure 4.1 - Shared Autonomous Vehicle http://www.busandmotorcoachnews.com/minnesota-testing-cold-weather-driverless-shuttle-bus/

4. CHAPTER FOUR - POSSIBLE APPROACH TO INTEGRATE SAVS

4. CHAPTER FOUR – POSSIBLE APPROACH TO INTEGRATE SAVs

When it comes to the integration of AVs, many questions arise. Some people are skeptics to the development of AVs, and some are more optimistic about AVs and their impact they will have on the city. However, both views are healthy for the development of future mobility solutions. We need to ask ourselves whether such technological development could solve the things we want to address and would benefit the society. How we could integrate it, that the community would accept it. However, the current incidents concerning safety and security breaches relating to the accident involving Uber AV and the data scandal with Facebook respectively create new trust issues. Moreover, we end up with an important question:

"Can we trust Autonomous Vehicles?"

To make a safe environment for the society with the deployment of AVs, we need a concrete vision and requirements that the vehicle manufactures, and mobility service providers have to abide. We are demanding that the vehicles comply with safety regulations, and the mobility providers operate within a specific legal frame of work keeping the business incentives, safety, and security in balance. However, we also have another fundamental question of the same magnitude.

"Can Autonomous Vehicles trust us?"

The question is difficult to answer as each person's actions are dependent on every person. Since the thesis has limited time to be handed in, the thesis has only brought up this question for the readers to envision the problems that could occur when we break our guidelines and expectations. The thesis is referring the development of AVs in general in finding the possible approach to integrate the vehicles. To have AVs as shared is a choice of using the vehicle sustainably.

4.1. THE VISION AND TIME-FRAME OF AVS

The development of AVs has a broad and distinctive vision in consideration to whom or whose perspective we look. It is a market-driven technological development that every aspect of the event has a unique business model that shape the way we use AVs. Besides, it is also dependent on international and national goals and aims of intelligent transport systems.

The ITS international and ITS Europe (ERTICO) is working with a vision for AVs and ITS technologies to provide Safer, Smarter, and Cleaner mobility. Mr. Bangsgaard[1] described that the challenges related to solving future mobility problems and fulfilling those visions depends on connectivity, automation, digitalization, multi-modality, electrification, cross-border connectivity, on-demand services and user-centric solutions. He further men-

1 Mr. Jacon Bangsgaard is CEO of ERTICO- ITS Europe.

tioned that the future of AVs is dependent upon those vehicles are autonomous, connected and electrified. (Bangsgaard, 2018)

Nationally, the primary goals of the ministry of transport concerning AVs and their future deployment are that the department is working to facilitate that people can use self-driving vehicles. The department has created competition with prize money of 100 million kroner for developing the best digital solution for future mobility. The objectives of this are to improve mobility and better transport solutions for the population. But, Mr. Solvik-Olsen stressed that this does not mean that people should own autonomous vehicles but provide a better transport needs by making AVs to be used through car-sharing services and collective transport service providers. (Solvik-Olsen,2018)

Concerning the development of AVs and automobiles, Norway has no mass producing automakers. The development of AVs is restricted to the testing of those vehicles. And there are tests of Autonomous shuttle buses happening in different place around the country. One of the test projects is PRT – FORUS in Stavanger. And the general plan is to use those autonomous shuttle buses as a supplement to the public transport. The vision of ITS Norway and public transportation providers such as Ruter and Kolumbus on the development and testing of AVs and the autonomous shuttle buses has three goals. Firstly, the possibility of those shuttle buses providing mobility as a feeder service to the ordinary public transport. Secondly, as a mobility service to distant areas with low population and limited public transport service. They are to function as on-demand mobility and would operate in areas where it is not actual to use large buses with a driver. Thirdly, they could drive in car-free regions and urban city centers as where small electric AVs are most veritable. (Hovland, 2018)

As the AVs are only present as pilot projects, there is no clearly defined vision for AVs and the future transport within the Norwegian Public Roads Administration (NPRA). But, the department is more focused on providing connected and autonomous vehicles for the future transportation. And Mr. Godal Holt emphasizes that

> ***"[…] It is important to differentiate between "Connected" and "Automated." The future is not just autonomous vehicles but to have connected autonomous vehicles. And further highlights that the NPRA is working in acquiring adequate knowledge into how connected autonomous vehicles will function in Norwegian roads, driving situations, and weather conditions […]".***

(Godal Holt, 2018)

When it comes to the Original Equipment Manufacturers (OEMs) such as Volvo, they envision that the future of the transport system will evolve into the use of Autonomous vehicles. And they genuinely believe that AVs will be a significant trend on urban mobility. However, Mr. Herland was reluctant to say what the vision and strategies are as they somehow intertwine to the business incentives. He said that they are developing personal autonomous vehicles of level 4, but he stated that Volvo cars understand and are following with the trend which states and other mobility experts are proclaiming that the future is about providing mobility services not just about selling cars. (Herland, 2018)

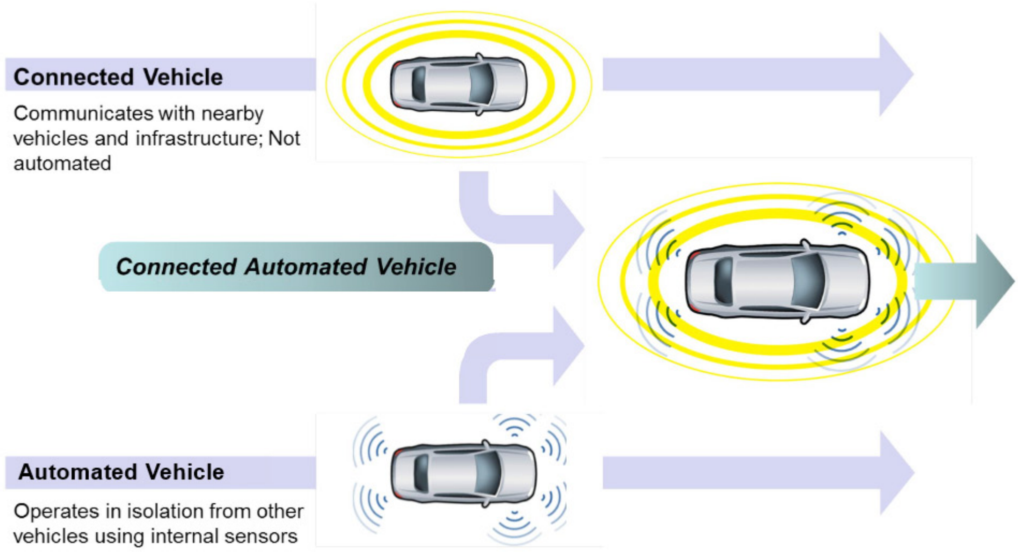

Figure 4.2 - Connected and Automated Vehicles (Greven, 2015)

The development of AVs is at an early stage, and all interviewees agreed that AVs are one part of the intelligent transport technologies. It is one of many tools or mechanisms that could aid in solving future development. The vision to the integration of AVs is dependent on how we want our society to develop and how we would like to shape our cities.

Expected Time-frame of the Development of AVs

The timing when autonomous vehicles would be out on the streets does not have a definitive time frame. Predictions from the car manufacturers and people working with the testing of autonomous vehicles show that in the next 15 or 17 years, we will have fully automated vehicles on our streets. In the meantime, the development of shuttle buses is being tested, and they would be in use as early as 2021. (Hovland, 2018) Moreover, Forus PRT AVs testing project has now officially received legality to drive in public roads. (Simonsen, 2018) This is a big step for Norway and Stavanger in becoming a leading organization in the development of SAVs and providing sustainable mobility.

The OEMs and car manufacturers have held a set of provisioned technological development secretly to the problems such as safety, security, and other issues. This secretiveness is due to the business incentives to be at the forefront of using intelligent transportation system and satisfying their customers when the time comes to use AVs in the streets. All they are waiting is the requirements and conditions expected from the society and the road authority to deploy them on the streets. (Madland, 2018)

The figure 4.3 shows the technology road-map for connected and autonomous vehicles. It shows the time-frame for each level of automation of the vehicle and the technological and connectivity capability. Those technological development are things which are the most common development. It shows that automation level 3 (L3) is expected to develop within the year 2025 fully. Legal complication and liability concern with automation L3 has stopped Volvo Cars from developing automation L3. They are working now with automation level 4 (L4). This change would allow L4 AVs to be deployed in the cities much earlier than is expected. (Herland, 2018)

Even though there is an exponential growth in the way the technological sphere is developing, there needs a set of requirements that must be in place to integrate AVs. Such conditions are beneficiary for all involved parties and most of all, for the people that will use them as well as the people that will be affected by the integration of the vehicles. New technological developments have unique challenges and barriers that keep them from being fully utilized. They require a new platform and a shift in paradigm. They will need new strategies and interventions to be accepted and benefit the whole society.

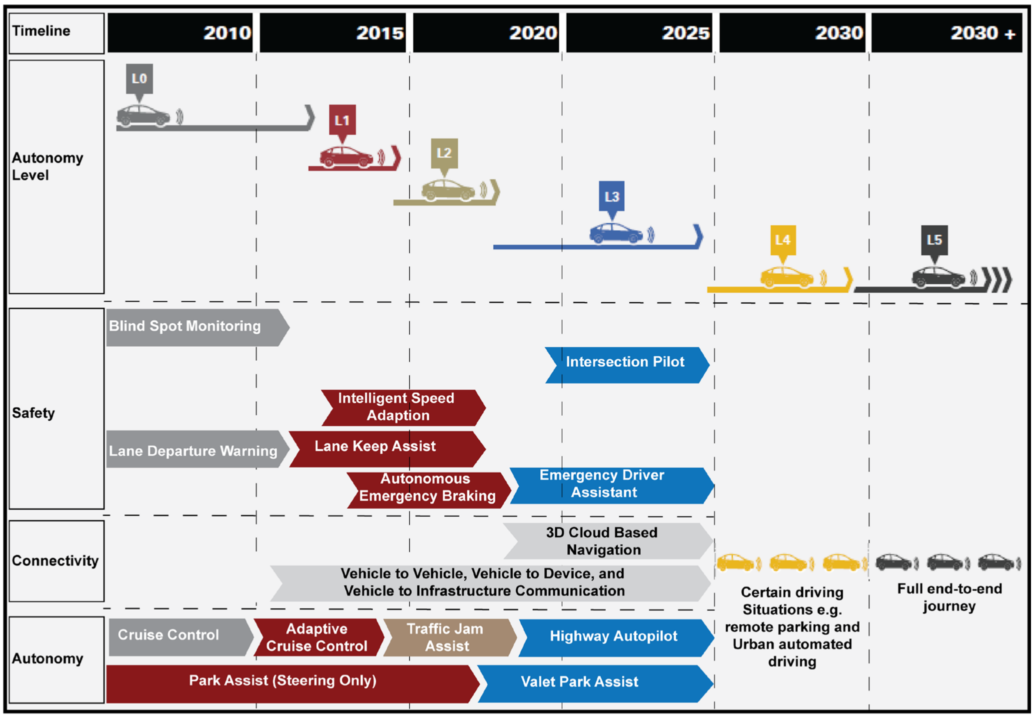

Figure 4.3 -Technology Road-map for Connected and Autonomous Vehicles (KPMG, 2015)

The time frame shown in figure 4.3 is the expectation of the general automation levels of the vehicles to function as efficient as the current cars. The time frame for SAVs such as the autonomous shuttle pods is however different. They drive at a low speed that managing the traffic could be not as demanding as AVs that are expected to drive at 90 km/h.

4.2. THE REQUIREMENTS TO THE DEVELOPMENT AUTONOMOUS VEHICLES

Technological developments are opening new challenges and new opportunities. AVs have a vast potential which would affect our daily life. The potential benefits also have their potential to create chaos with the way our communities and society function. Requirements are necessary to prevent any disruption within the society keeping situations and possible downfalls in check with new technology. There need to be requirements for AVs to be integrated into the existing infrastructure and have a specific responsibility to function as a means of providing mobility to the society. The thesis has categorized the requirements in three main topics; provisions for the technological viability, demand to have standards and needs to have laws and regulations.

4.2.1. TECHNICAL CONDITIONS AND STATUS

Change is happening fast that we could not comprehend the acceleration we have seen with technological development. And AVs technological development is a new business platform with a very vast spectrum that includes OEMs, telecom industries, and many different vendors. And everyone is working to be on the forefront. Countries such as USA, Japan, and China are in the driver seat on the developing of self-driving vehicles. (Madland, 2018) And Norway is one of the countries that are testing shuttle buses. (ITS Norway, 2018) And Forus PRT has test driven Autonomous shuttle buses for about 3000 kilometers on a closed area. (Lohne Marken, 2018)

When it comes to the technological development of AVs, there are no requirements that are upheld as a low in any country that is working with Autonomous vehicles. And, Norway has not prepared any conditions as well, since it does not have car manufacturers. (Hovland, 2018) But, some of the leading countries on the production of autonomous vehicles have prepared technological requirements recommendation and vehicle performance guidance to the state and the OEMs to create a safe use of AVs under real-world conditions. (National Highway Traffic Safety Administration (NHTSA), N/A)

The technological development of AVs and their implementation is dependent on the events happening in the vehicle development and in providing an infrastructure both digital and physical that supports those vehicles.

I. Vehicle Development

The vehicle development and the status of that development are not apparent at the moment. Some of the developments that are known include such as Advanced Driver Assistance Systems (ADAS), Sensor technologies, Communication technologies. The OEMs and their suppliers understand that their technology could become the central feature differentiating automotive brands, and their revenue sources. (Choi, Thalmayr, Wee, & Weig, 2016) The new cars produced at the moment are using most of those technological developments. Those technologies are part of the development of AVs. The development of those is exponentially getting advanced. (Hovland, 2018) The status of those vehicle technologies is always changing that they get outdated while the thesis is being written. However, general description of some of those developments is mentioned below.

A. Advanced Driver Assistance Systems (ADAS)

The different ADAS are an essential part of the AVs development, and they are dependent on four major control units. They depend on perceiving external data and immediate environmental situations (Sensors), and the need to store and update geological and infrastructure information (Mapping). They also depend on the need to make decisions on processed data (Processors – electric control units (ECUs)/ Microcontroller units (MCUs)) and software algorithms to provide output to the driver or specify how the system should intervene in vehicle control. (Choi, Thalmayr, Wee, & Weig, 2016) Transport Economy Institute (TØI) had done a study on some of those ADAS, and they found out that ADAS could reduce the number of killed or seriously injured (KSI) in Norway. The results are shown in percentage of the potential reduction in KSI. (Høye, Hesjevoll, & Vaa, 2015)

No.	ADAS TYPE	Prediction KSI reduction
1	Automatic Cruise Control (ACC) with Forward Collision Warning (FCW)	5.3%
2	Forward Collision Warning (FCW)	-
3	Automatic emergency brake (AEB)	-
4	Pedestrian/Cyclist Warning with Automatic emergency brake (AEB) and blind spot warning	Pedestrian 7% Cyclist 8%
5	Lane departure warning (LDW)	6.4%
6	Intelligent speed adaptation (ISA)	Overridable 7.5% - Mandatory 16.2%
7	Alcohol/drug ignition interlock	11.1% to 14.6 %

Table 4.1 – TØI prediction on the number of KSI reduction with the introduction of ADAS. (Høye, Hesjevoll, & Vaa, 2015)

Forward Collision Warning (FCW) and Automatic emergency brake (AEB) are two ADAS systems which are compatible fittings to other ADAS systems such as ACC. (Høye, Hesjevoll, & Vaa, 2015) Their prediction to aid reduce KSI are not given separately but are used as a compatible parts of ACC and Pedestrian and cyclist warning systems.

B. Sensor Technology

AVs are using different sensors to meet the sophisticated demand of driving autonomously and having the ability to recognize and see 360 degrees around the vehicle on all kinds of weather and time of the day. Some of them are mentioned below.

- LiDAR (laser) System (Light Detection and Ranging)
- Vision (Camera) system
- Radar system
- Supplemental Sensors – such as Audio detection sensors and GPS – positioning sensors.

Those sensors have been developing, but not all of them are robust enough to be considered as an autonomous grade. They still require further testing and developing. (COMPASS, 2012) The sensors are developing, and the expectation is they will be much developed. For an autonomous vehicle to be allowed to drive in the streets, those functions must show that they could function 100% and the vehicles need to show that they can handle unexpected situations and recognize obstacles. (Hovland, 2018)

C. Communication Technologies

AVs require vehicle to vehicle (V2V) or vehicle to infrastructure (V2I) communication. Those technologies allow AVs to communicate to each other and to the infrastructure. For AVs to be implemented on the existing infrastructure together with the existing vehicles, would require not only the AVs to communicate to each other but they need to communicate to the manual driven vehicles. There also need that the manual vehicles to communicate with AVs. In order, the normal vehicles to communicate would require some sort of V2V communication to those vehicles. Additionally, the Original Equipment Manufacturers (OEMs) of different auto manufacturers are also developing independently their own communication technology. Mr. Scharfe emphasized that one of the challenges for the AVs is that vehicles from different manufacturers do not communicate to each other. There is an understandable business computation among them that is creating this technological compatibility problem. He also highlights the need to upgrade the existing vehicles and the role of the car manufacturers in providing a device that could be fitted to the manual vehicles that allow them to communicate with other vehicles. . (Scharfe, 2017)

There is a huge problem with the number of old cars in Norway which was also brought almost by every one that was interviewed for this research. Even the Minister of Transport Mr. Solvik-Olsen highlighted the problem and the need to re-regulate the age span of the car park in Norway. (Solvik-Olsen,2018) And Mr. Hovland further stressed the need to share data, and that if any car manufacturer wants to sell an AV, they need to share their data. He also acknowledges the challenges to having open data and the need for a digital infrastructure that could carry this data. (Hovland, 2018)

II. Digital Infrastructure and Physical Infrastructure

For AVs to be integrated, they need physical and digital infrastructures as much as the technologies that allow them to be autonomous. The digital infrastructures such as BIG Data, Maps, and 5G- mobile connections are some of the requirements that need to be in place for the vehicles to function safely in real-world time. When it comes to the physical infrastructures, the vehicles are expected to function on the existing infrastructure, which we do not need to change our infrastructure. Even though a complete change of the physical infrastructure is not required, constant maintenance is required to keep the roads to a standard that the vehicles can drive on them. (Hovland, 2018)

A. Maps

The existing road-maps are not precisely accurate to the position of a person, a vehicle, or the surrounding. The introduction of AVs emphasizes the need for a highly precise map to know exactly where the car is on the road in real time along with its surrounding. It is understood that having accurate maps would reduce hazardous safety situations. (Schumann, 2014)

At the moment, there is a work in progress for a deeper level of granularity to create precise maps. A future localization positioning technology which is able to identify a vehicle and its surrounding on a map with an accuracy of around 10 – 20 centimeters is being developed. This type of map would recognize lane marking types, intersections, signs and would enable a vehicle to know which lane it is in on multi-lane highways. The maps would also recognize lane location with regard to the nearest vehicle or object. (Schumann, 2014)

Trond explains that work is underway with Tomtom and AirMap to provide a more detailed and precise map. He also stressed that the need for map authorities and the road authority to engage with those vendors so that speed limits and pedestrian crossings and other road signs could be included with the detail maps. (Hovland, 2018)

B. 5G-Autonomous Driving Connection and Big Data

The fifth-generation mobile networks (5G) is a mobile network faster than the version 4G. It is a purpose-built technology that is designed and engineered to facilitate connected devices and automation systems. Autonomous driving would require a fast connection to transfer big data that are large and complex to be analyzed in real time. (Somisetty, N/A)

Telenor is working on the introduction of 5G in Kongsberg as the first city to test the technology in autonomous bus driving, drones, emergency communications and eHealth. The technology is expected to transform many critical social applications such as traffic management, health services, and critical communication services. (Oesterud, 2017)

C. Road Infrastructures

The first and foremost criteria for AVs is that they have to be driven in the existing infrastructure. Minister of Transport Mr. Solvik-Olsen meant that

> ***"[…] It does not need a separate infrastructure for the AVs but needs a good infrastructure. And they need to be driven in the existing infrastructure with the existing vehicles. And he also meant that if we are going to wait until the existing car park is to be changed with AVs, then AVs would not be a reality. […]"***

(Own translation) (Solvik-Olsen,2018)

The road infrastructure may not need to change at the moment as long as the manual driving vehicles are on the streets. How the streets are built with the contingency for safety will not change. But the predictions are that AVs will reduce the need for an extra space and congestion, that we need to re-structure the road infrastructure and take back some of the space to different purposes. (Hovland, 2018)

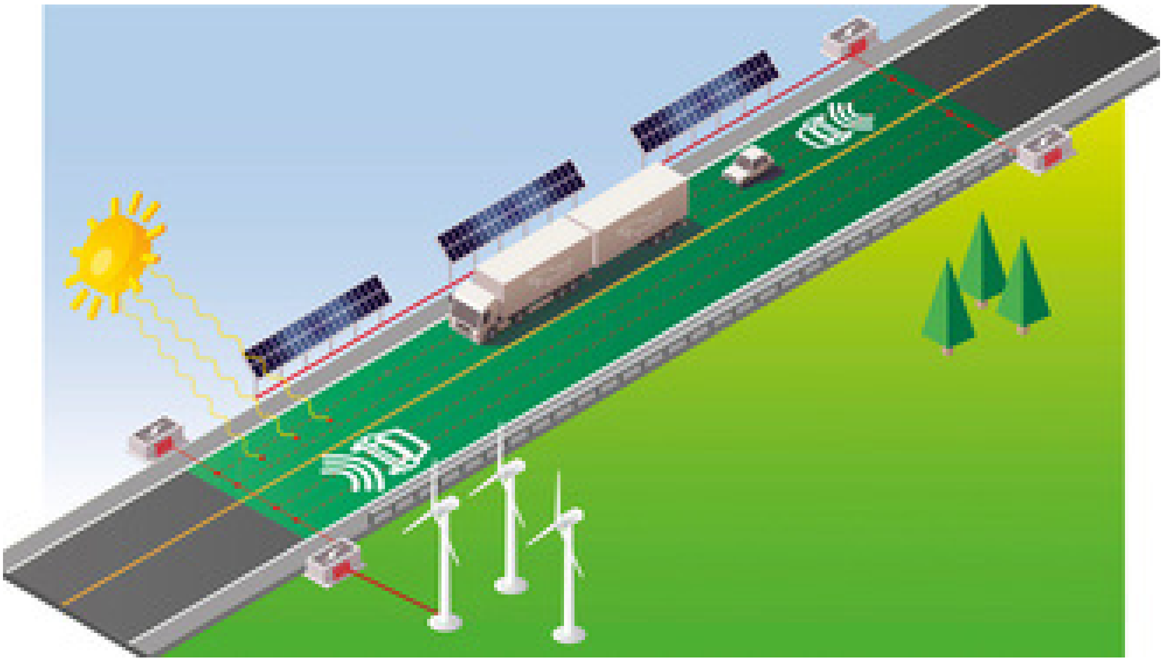

Figure 4.4 – Wireless charging pavement (Valle, 2018)

One of the future possibility is that we could introduce a wireless road pavement charging mechanism to charge those vehicles while they are on the move. Such development would also aid in reducing the need for space to park and charge within the city center. The figure 4.4 shows the test technology project ElinGo that is underway to charge vehicles while on motion in Norway. The technology has been tested in America and could charge a bus with 200 kilowatts wireless. And the technology is on the way to Europe in 2019. (Valle, 2018)

4.2.2. STANDARDIZATION

Standardization is a program that helps minimize and simplify things and maximize utilization efficiency and provides convenience for users. And any written rules are called Standards. Standards are always market driven. Most of the time, they are provided when there is a demand for standardization. (Norway Standard, 2017)

The Norwegian Standard organization (Norway Standard) is the organization that represents Norway on the international organ and makes easy for Norwegian industries or stakeholder to participate in the international competitions. Norway Standard has a commitment to follow the standards published by the European Committee for Standardization (CEN) and The European Telecommunications Standards Institute (ETSI). But do not have any commitment to International Organization for Standardization (ISO). The Norwegian Standard revises any standards published by ISO with regard to the norms and requirements of the Norwegian society and business. (Norway Standard, 2017)

When it comes to the standardization of the intelligent transport systems (ITS), three standardization bodies are of interest to the NPRA. These are CEN TC 278, ETSI TC ITS, and ISO TC 204. Those bodies have made many standards that are relevant to connected autonomous vehicles. And there are around 661 standards which are directly relevant to connected autonomous vehicles. The majority of those standards are done within the international standardization organizations such as ISO, ETSI, and CEN. ISO published 381 of those standards, where 18 of them are adapted to European standards by CEN. ETSI and CEN are the major European standardization organizations and have published 99 and 58 standards respectively. (BSI & Transport Systems Catapult, 2017)

Norway has been active in the standardization of ITS systems and has participated in the standardization of automatic vehicle and equipment identification as shown in the figure 4.5. The figure shows the participation and working groups within the ISO TC 204. Norway is one of the 28 countries that are contributing to meetings, participating actively and have an obligation to vote on the published standards.

When it comes to the standardization of autonomous vehicles and connectivity, Norway is only following the development that is happening within CEN, ETSI, and ISO. At the moment, Norway does not have any participation in the current standardization of autonomous vehicles, due to the lack of big OEMs or car manufactures. (Husøy, 2018)

However, Lars E Jensen has acknowledged that the need to participate. He said

> ***"[...] It is comfortable to sit in the back seat ... we can wait for new standards to come, but then we have little or no impact on the content of the standards, but we will have a great impact if we are actively involved in development. [...] Then we will get the best standards if we are sitting in the front seat and take control, ensuring national interests into standards. [...]"***

Own translation (Lars-Erik-Jensen, 2018)

The challenges with standardization of ITS development are that usually standardization is done when a technology has been used. And ITS technologies have not fully been utilized that make them difficult to standardize. The reason is that providing a standard in the early stage requires that you go through a fine line between providing the manufacturers a foundation and initiatives for further development or restricting them with guidelines for further development and innovation. This is a fine line between competition and standardization. Mr. Husøy mentioned that for Standard Norway, there is a deficiency of the essential knowledge and experience to prepare standards in the field that makes it more difficult. Preparing those standards requires knowledge and expertise from different stakeholders and experience of different scenarios of the functionality and use of the technology. He also mentioned that, OEMs have held on to the status of their technological development secretly which makes standardization of AVs difficult at the moment. He also emphasized it is understandable that they would not reveal the technology as the technology is their edge in the business arena. (Husøy, 2018)

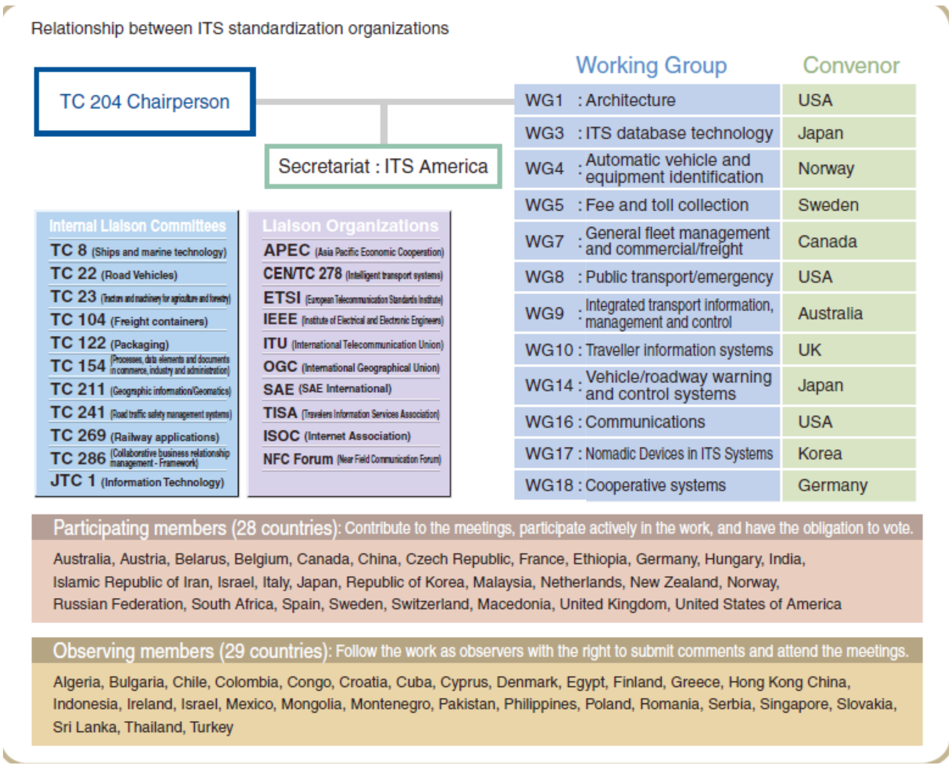

Figure 4.5 - Relationship between ITS standardization organizations (Society of Automotive Engineers of japan, 2017)

There is one standard that is published by the UK standardization organization (BSI – British Standard Institutions) and the Transport Systems Catapult (TSC). The standard identifies the barriers to the development and deployment of Connected Autonomous Vehicles (CAVs) in the UK including the lack of common standards and policies, the technological acceptance, the reliability of existing infrastructure, integrating CAVs with existing transport systems, and assessing the performance of CAVs. (BSI & Transport Systems Catapult, 2017)

A UK standard strategy has surveyed within the CAVs stakeholders to understand the challenges facing the development of CAVs industries. And, they gathered seven major priority areas. The participants had put functional safety as a first priority to be standardized. The need to have a common communication standard was set as the second priority. Cyber resilience and Data issues such as privacy, usage, and access were placed consecutively as third and fourth choices. Everything about roads and roadside physical infrastructures was also mentioned as a part of the topics needed to be standardized. Vehicle security was placed as the sixth priority topic. Last but not least, the need to have a standardized road network management was recognized by the participants. (BSI & TSC, 2017)

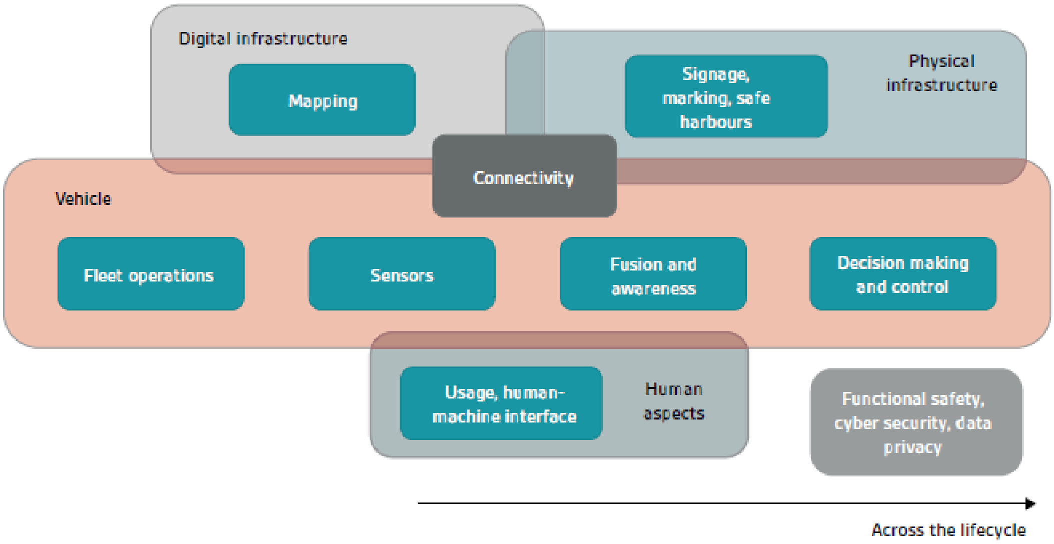

Figure 4.6 - The scope of Standardization done in the UK (BSI & TSC, 2017)

The UK standard has worked on the standardization strategy with a proposition that connected vehicles and autonomous vehicles as two distinct but overlapping topics. And have created the scope of the standard in the figure 4.6. Different countries and standard organizations have been researching and developing to solve those major priority topics.

At the moment, none of the standard published has been passed as a mandate. Moreover, there is intense competition to the standardization done by ISO, CEN or ETSI from the telecom industries. There are a huge business market and a massive profit to be made that they are lobbying to get their standards instead of the standard recommended by ISO. (Hovland, 2018)

Although the standardization of ITS developments does not differentiate between the different functions of AVs, the SAVs would require a functional uniformity that needs them to be used without being constrained to a specific area, region, or age group. Mr. Husøy mentioned that Standard Norway had made a standard for all public buses recently. And Mr. Husøy acknowledged that the same could be done if autonomous vehicles are to function as car sharing or public mobility providers. However, he also emphasized that there is no enough knowledge and experience on how they will perform on Norwegian road and weather conditions. (Husøy, 2018)

4.2.3. POLICY AND REGULATIONS

At the moment, no policy or regulation is available for the implementation of AVs. All the countries that are working with autonomous vehicle development have worked some form of strategy as a recommendation to OEMs and car manufacturers which they could decide to follow or not. The U.S. Department of Transportation has published a Vision for Safety 2.0 policy document for voluntary guidance. The report touches different aspects of safety that the OEMs have to look and provide that the vehicles could manage. The material looks into 15 safety assessment areas. (US Department of Transportation & NHTSA, 2016)

The development of the policy and regulation matter is a delicate matter that it is understood that it will take time. The technological development is developing fast that there is a question between what should be regulated and what should be standardized. Mr. Husøy meant that all situations that could end up in court should be regulated to facilitate and simplify the implementation of AVs. (Husøy, 2018) And the Ministry of transport is following the development occurring in other countries and is working with the neighbor countries. But, Norway is not active in the development of AVs as it does not have car manufacturers. Nevertheless, Norway has provided a policy that allows the testing of AVs in Norwegian roads. (Solvik-Olsen,2018)

Law for testing of self-driving vehicles

At present, the Norwegian parliament has approved a new law to test self-driving vehicles on Norwegian road. The law has six chapters covering from acquiring of permission to testing those vehicles, safety requirements, liability and data security, supervision controls and other regulatory policies. The law does not demand that a driver inside or outside of the vehicle. It allows the vehicle to be tested in autonomous mode. This is much improved version of the policies that are developed in Sweden and Germany. Mr. Solvik-Olsen highlights that this gives an edge to the testing of AVs for Norwegian companies and allows them to be in the forefront of the development and testing arena. (Andersen, 2017)

The law requires several conditions to be fulfilled before a permission for testing could be granted. For the application to be approved, the applicant must show that the vehicle meets the requirements for traffic safety, vehicle control and emergency procedures. And it also points out that there should be a person that takes responsibility to conduct the testing in accordance with the applicable rules and ensure that the vehicle is operated in a safe manner while driven autonomously. And he also takes liability if an accident occurs. (Stortinget, 2017)

The law also covers policies that covers personal securities and data management. The law states in paragraph § 12 that necessary personal information from areas outside of the vehicle, and inside the vehicles where the general public has access, can be collected and stored without consent from those using the vehicle, provided that the material is deleted or anonymized within seven days, unless otherwise provided by law or regulations given pursuant to law. And further states in paragraph §14 that data collected can only be used to research and development works with regard to the testing of self-driving vehicles. (Stortinget, 2017)

And also the law states that illegally using of self-driving vehicles and not follow to the policy given for testing of self-driving vehicles is punishable in the same manner as the paragraph §31 the road traffic act. (Stortinget, 2017)

4.3. BARRIERS TO INTEGRATE SAVs

The thesis has identified six obstacles for the development of AVs and their implementation. Those barriers are not specific to Norway, but general situation related to the development of AVs. First and foremost, the barrier to the implementation of AVs in Norway is that Norway is not actively developing AVs. As a result, this will also have both economic and technological consequence to the nation as well as to individual businesses. The selection of those barriers is all related to safety. Moreover, they are shown in the figure below and are further discussed.

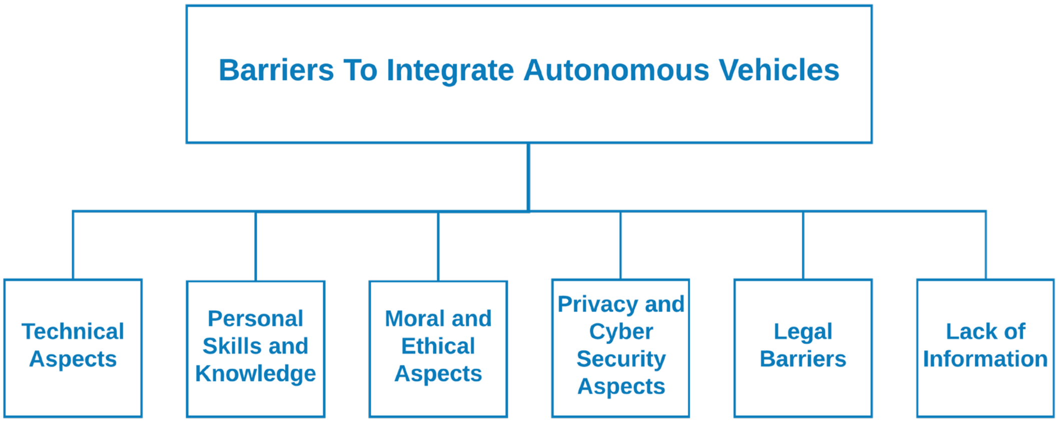

Figure 4.7- Barriers to the integration of SAVs

4.3.1. TECHNICAL ASPECTS

The development of AVs is advancing very fast, and every aspect of the technical parts is much advanced than it was. It is expected to be much more sophisticated in the future. The primary challenge that could obstacle the implementation of AVs is that reliability of the vehicle to function safely. Reliability is the driver of the vehicles acceptability in the society. The manufacturer's need to prove that vehicles could drive in real time in the real world and document the results. (Hovland, 2018)

The introduction of Big Data and 5G mobile networks is thought to facilitate the implementation of AVs. Driving AVs would require a reliable connection and computing systems. AVs would generate a massive amount of data to be computed and transferred in real time. Moreover, many companies are moving the computing to a cloud server to accommodate the Big Data. The biggest challenge is providing a reliable connection at all time. If the link fails, the vehicle could jeopardize the safety of the passenger. Thus, 5G- connection needs to prove that the connection could be reliable in the testing of AVs for further implementation of the vehicles on Norwegian roads. (Anadiotis, 2018)

Mapping, sensors, ADAS have also to be more advanced and reliable. They have to show and maintain that they can be used in all kinds of weather condition, time of the day. As Brad Davey of ArcelorMittal outlined

> ***"AVs are going to change the world […], but they will certainly bring issues that we may not have foretold."***

(Nash, 2017)

The Technical aspects of the vehicles or the infrastructure are going to change the world, but the changes have to be managed. To rely on those developments to function at all times is one of the primary safety issues that need to be solved. Until these vehicles show they could handle the real-time in real-world situations, technical reliability concern will be one of the main obstacles to the deployment of AVs.

4.3.2. TRANSFORMATION OF THE POPULATION TO DIGITAL TALENT

The development of AVs is dependent on the revolution happening in the digital world. The digital revolution is becoming the key driver of economic growth. The transformation to a digital world has changed the way we work, communicate, do business, and how we do our everyday domestic activities. By the end of 2013, the number of people in the world who have grown up with digital started to outnumber those that have to adapt to the digital transformation. Moreover, by the end of 2016, there were about 3.2 billion people who were connected to the Internet worldwide. (Probst, Pedersen, Wenger, & PwC, 2017)

The primary missions and goals of self-driving vehicles are that they would provide mobility for everyone, increase safety and increase efficiency. (Waymo, 2017) When we talk about offering mobility to everyone, we are talking about providing opportunities for people which could not drive a manually driven vehicle because of age, technical ability, and

Figure 4.8 - General Motors inside of their AV (Ayre, 2018)

financial ability. One central part of the challenge is the people who need it most has to be able to use it themselves.

Not everyone can find or manage the things one needs in electronic equipment. Moreover, most seniors have difficulties with maneuvering or managing the digital material, such as a smart-phone or even computers for some. All people do not have the same capacity to understand or grasp new developments or electronic equipment. AVs are more advanced systems than the smart-phones or other electronic equipment. Hence, AVs need to have an easy steering mechanism for everyone or the society need to be transformed into a digital talent to use them.

4.3.3. MORAL AND ETHICAL ASPECTS

Safety is the primary objectives of AVs development. They have the potential to reduce traffic significantly, reduce pollution and decrease the number of crashes by up to 90%. (Robertson, Meister, Vanlaar, & Hing∗, 2017) Then again, there will be situations that AVs have to decide on incidents that are unavoidable. An online survey conducted in the U.S. shows what people expect with how AVs should behave. The study showed three scenarios where AVs may make a decision: A) killing multiple pedestrians or one pedestrian, B) killing one pedestrian or one passenger, and C) killing several pedestrians or one passenger. (Jean-François, Azim, & Iyad, 2016) However, Mr. Scharfe argued that there should not be a situation for AVs to choose as there is none present for humans. (Scharfe, 2017) At the moment, there is no regulation or guidelines for AVs in Norway, how they should behave in such kind of situations. (Hovland, 2018)

Most expected accidents involving AVs is not that AVs would be the source of the crash. Accidents will occur as a result of misuse of the vehicle, or the car will be involved in an

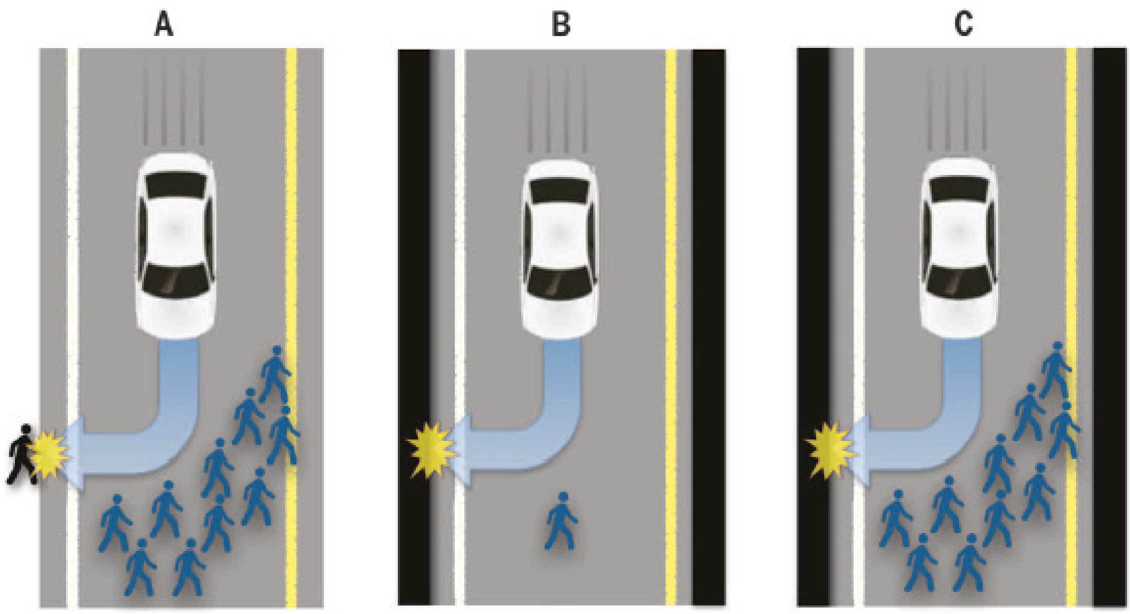

Figure 4.9 - Three traffic situations in unavoidable accidents (Jean-François, Azim, & Iyad, 2016)

accident with a manually driven car. People's misjudgment of traffic situations and not following the traffic rules would lead to more accidents as AVs will always follow the rules. (Hovland, 2018) The recent incidents involving Uber's autonomous test vehicle, and Tesla's Autopilot shows that the need for legal guidelines and civil and criminal liability laws regarding AVs.

The First Death Accident involving Autonomous Vehicle

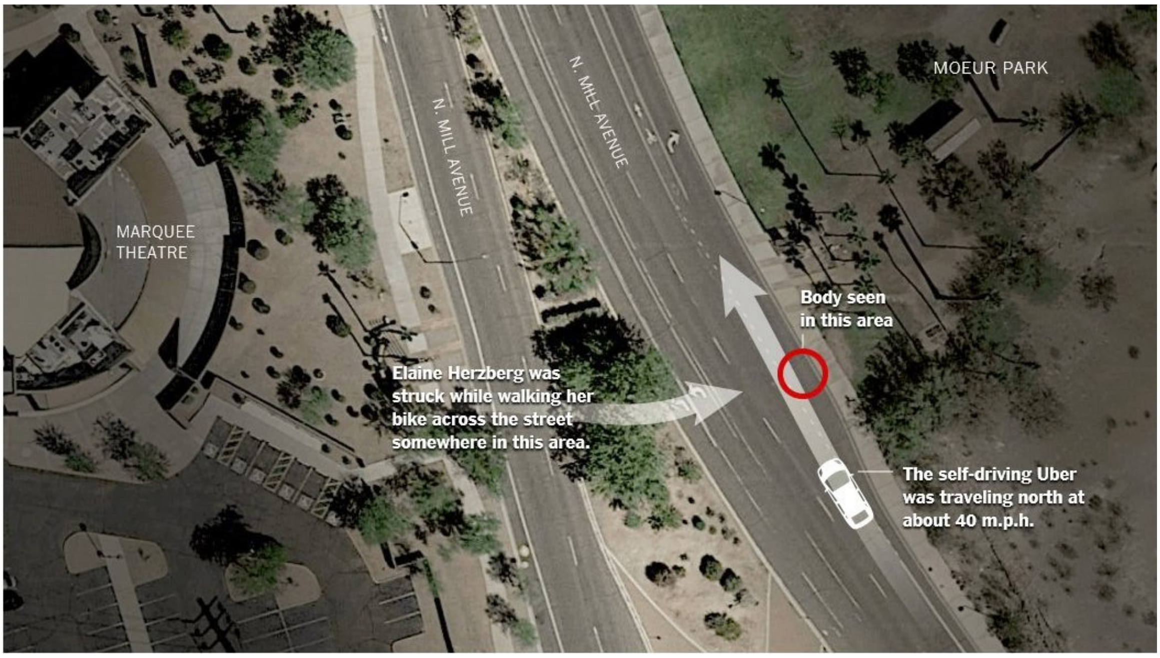

Figure 4.10 – Uber AV accident in Arizona (GRIGGS & WAKABAYASHI, 2018)

On Monday 19, March 2018, a woman was killed in an accident involving an autonomous vehicle. Uber was testing the vehicle with an Uber Autonomous technology in a Volvo XC90 on the road. Figure 4.10 is showing the situation regarding the accident. Investigation to the accident has shown that the vehicle had manually turned off the Automatic Emergency Brake (AEB). However, a vehicle that follows the European regulations would have had AEB, and it is not allowed to manually turn-off. (Marius Valle (b), 2018)

Last year, there was also an accident involving a Tesla, autopilot. The investigation had concluded that although the technology had performed as it should, it lacked a system that prevents drivers from misusing the technology in the vehicle. Robert L. Sumwalt, the chairman of the National Transportation Safety Board, had said that the accident was a combined effect of human error and the lack of sufficient systems. (BOUDETTE & VLASIC, 2017) Both accidents had both human error and lack of technological systems operating. Those accidents have opened a new topic in the development of AVs and the need for regulations for a vehicle while operating in the real world.

With manually driven vehicles, most accidents are not intentional, but the situation occurs with people misjudging the traffic situations or human error. With AVs, the accidents could be malfunctioning of the driving technologies or manually turning off of critical operative systems and the errors could be regulated and prevented. However, they will still require people to follow the rules on the road.

4.3.4. PRIVACY AND CYBERSECURITY CHALLENGES

When vehicles become more automated and connected, there is a challenge in protecting the vehicles from cybersecurity attack and privacy problems. The first part of this challenge on autonomous vehicles is the issue of privacy. The different autonomous vehicles manufacturers are developing a technology where each would operate its vehicles remotely. However, when data is processed by different manufacturers and with the possibility of exploitation of data creates a challenge which must be addressed to protect the privacy of each user. (Rand Corporation, 2014) The primary challenge of the privacy issues and data gathering is that the OEMs and car manufacturers see the next business model as the selling of service and digitalization. They are reluctant to share or regulate the IP address. (Hovland, 2018) (Husøy, 2018) The Facebook scandal is one of the consequences of not regulating data collected.

Facebook Privacy Scandal

The Facebook data breach scandal is a wakeup call to the use of data from service and communication providers. The news has been flooded with the opinions of people that personal data collected need to be regulated. On the wake of autonomous vehicles, there should have

Figure 4.11 – Facebook data breach (McNamee & Parakilas, 2018)

a precise regulation that protects the privacy of people. There should have a clear guideline for collecting personal data and selling of data to the third party. (McNamee & Parakilas, 2018)

At the moment, the EU General Data Protection Regulation (or GDPR) has prepared a new regulation to protect the privacy of every person that uses the Internet which came into effect on 25 May 2018. The regulation prevents every company or institution (private or public) that collects personal data to inform users and ask for consent. Moreover, people have the control of their data and privacy. (Jaffe & Hautala, 2018) The regulation could facilitate the integration of AVs and provide people with insurance their data will not be misused.

There is always a fine line between privacy and surveillance. For safety reasons, there needs to have surveillance mechanism on board the AVs. On the pilot project, Forus PRT has decided not to have a surveillance camera within the vehicle. Mr. Hovland has argued that when using autonomous shuttle buses, it is impossible to not have a camera onboard the vehicle for security reasons. He mentioned that he does not understand the decision of Kolumbus test project for not wanting to have a camera. (Hovland, 2018) Mrs. Lohne Marken confirmed that they (PRT Forus) would not have a camera on board on the test vehicle. However, she stressed that if we decide to have a camera onboard the vehicle, it would not be a problem as long as we have the same surveillance regulation as cameras used in the current buses. (Lohne Marken, 2018)

The other part of the challenge is the cybersecurity challenges of such vehicles. The vehicles should be able to detect failure and breaches of the system and act safely not to in danger the passengers and road users. (Rand Corporation, 2014) The integration and implementation of AVs are dependent on those vehicles could communicate to each other. And the use of 5G and Big Data opens a new set of cybersecurity problems. (Anadiotis, 2018) In recent years, Tesla has been a victim of trophy hunting hackers on their Model S and Model X cars. Other OEMs such as Mitsubishi and Nissan have also been targeted where steering, braking, and private vehicle data being compromised. Although those activities have been conducted as research scenarios, they show the challenge ahead in the development of AVs and cybersecurity challenge. (Holmes, 2017)

Second research was conducted on Tesla Model S last year July 2017. The research exposed gaps in onboard Wi-Fi and 3G connectivity systems. They hacked the vehicle, and the touchscreen was disabled. They also controlled the brakes remotely, and windscreen wipers were disabled while driving through heavy rainfall. (Holmes, 2017)

The primary goal of AVs development is providing a safe, accessible and environmentally friendly mobility. Privacy and cybersecurity are one of the main threats to the safety of the vehicle users and people that come in contact with the vehicle. Privacy challenges could be regulated, and we could manage who is collecting or storing data. Cybersecurity is not something that could be regulated, but the technology has to be robust to prevent disastrous situations.

4.3.5. LEGAL BARRIERS

In the pursuit of AVs development, the technological development has developed with an exponential factor, while the regulatory part has not advanced as it should. Worldwide, the main objectives of the regulations are to provide the best road safety. And when it comes to AVs, the main concern is that they have to provide or prove that they are safe to drive on the road in real time. Providing legal guidelines to critical situations such as public policies, traffic code, technical standards, criminal and civil laws with regard the implementation of AVs and their functionality in the road is the main challenge. (Hovland, 2018) (Madland,

2018) (ITS Norway, 2018)

The Vienna convention is one of the obstacles to the implementation of AVs. The Vienna Convention states that a vehicle requires a driver and the driver must be in control of the vehicle at all times. Amendments to the Vienna convention also states that vehicle systems that influence the way a vehicle operate have to be a type that is approved or the system can be overridden or switched off by the driver to get conformity with the convention. And, the convention is only applicable up to level 3 of AVs. (Barabás, Todoruţ, Cordoş, & Molea, 2017)

The UN ECE Regulation 79 on steering also restricts automatically commanded steering not to function more than 10km/h and only vehicles with corrective steering functions could be permitted to drive above 10km/h. These regulation obstacles any automation level above level 2. (Greven, 2015)

Countries that have subscribed to the Vienna convention and UN ECE Regulation 79 on steering need to agree on a new convention to accommodate AVs. And Norway is one of those countries that have subscribed to this convention on road traffic. (UNECE, N/A)

The AVs development is international influenced matter. The development of regulations is dependent on the vehicles to function in every country. Norway been part of the international and European Union, the policy matter is a joint work with its neighbor's countries. The vision of the AVs is being shaped by various stakeholders who have their interests in advancing particular framings. Although some research projects and testing of AVs is funded nationally in Norway and Europe, Strategic European documents and Norwegian Strategic documents do not widely discuss about AVs. And this could affect and delay the implementation of AVs. (Schreurs & Steuwer, 2016)

4.3.6. LACK OF INFORMATION

At the moment, there is lack of information about the development of AVs from the OEMs, car manufacturers and vendors. The information that is out there is not sufficient for the planners and state representatives to start to include in their plans as well as to start the process of regulating the AVs. In Norway, there is no information about AVs in the web pages of the ministry of transport or the Norwegian public road authority. Even Mr. Hovland, Managing Director of ITS Norway, and Mr. Solvik-Olsen, Minister of Transport, acknowledged that the need for an information center which aids small business owners and other interested groups to get the information they need. (ITS Norway, 2018)

4.4. INTERVENTIONS AND STRATEGIES

> ***"The technology is racing ahead of everything else, including agreements to use the technology, how to regulate them, and how to ensure them."***
>
> John MacDuffie (Gleave, 2016)

Technological development is advancing at speed not actual comprehensive to the rest of the world. The world is still grasping on "what" and "why" related questions of autonomous vehicles. And there have been few attempts to answer how would that development could be regulated, how to use them, or how would they impact urban planning. The governmental strategy approach has two equally tricky challenges which coexist and must be solved. They are, firstly, the technical challenges that need addressing concerning regulations and viability. And the second one is the economic opportunities that need to materialize. The strategies have to be seen not only as economic and transport efficiency gains but also, they need to consider if the development can be a strategy for places, cities and the urban development. (Gleave, 2016)

All predictions on autonomous vehicles direct that the cars could reduce congestion problems, safety and economic viability reducing the need for a driver or the need to build new roads, …etc. Studies showed that regulatory and policymakers to be aware of motivational variables. There is perceived usefulness that the vehicles could change public transport to be more effective. There is also a perceived enjoyment they could provide while driving, a perceived safety that they could reduce accidents by eliminating the human error factor, and a perceived self-identity of a smart city that comes with the development of AVs. (Folkestad, 2016) However, supposed motivational variables are not actual variables but things that need to be analyzed and regulated to prevent undesirable outcomes.

The Norwegian public road authority recognizes their role in the development of ITS. In the action plan for the NTP, it mentioned that the NPRA to take a leading role in developing legislation and regulations to ITS. Further, the plan recognized that achieving practically those motivational variables are far more complex and they expect an extended transitional period with traffic safety challenges. Also, they recognized the need to examine the impacts of introducing AVs would have to the people and the competence needed for both new and existing drivers. (Staten Vegvesen, 2018)

4.4.1. TECHNICAL INTERVENTIONS AND STRATEGIES

The strategies and interventions to the technical aspect of the AVs is kind of complicated. The strategies are dependent to every OEMs and vendors that is working out there. Mr. Herland had mentioned that the communication part of AVs is going have a commonality, which the communication protocols will be open allowing the vehicles to communicate to each other. This is the key to connected and autonomous vehicles. (Herland, 2018)

All AVs communication systems are developing in the direction of executing the data transfer digitally. And the telecom companies are now developing the digital infrastructure. The challenge is not just the technical algorithms but also there are a lot of places that communication coverage is very low or do not have. However, Norway is on the forefront as it is one of the few countries that is adapting 5G communication networks. And this is expected to aid achieve the needed network. (Herland, 2018)

Providing better mobility is not only based on the vehicle to be autonomously driven but the need to communicate with each other and know what is happening in the distant area. So that to implement AVs they need to communicate each other. (Godal Holt, 2018) On the contrary, Mr. Herland argues that if the implementation is to wait until all vehicles have to communicate to each other, then they will not be actual. And he stressed that the OEMs must find a way to solve this without basing the future of Autonomous vehicles on communicating to V2V. He logics his idea that there is a lot of old cars and to shift those vehicles would still require more than 10 to 20 years. He said that there should be a mechanism where they could drive side by side to the manually operated vehicles. (Herland, 2018) And, Mr. Scharfe have different opinion than Mr. Herland. He mentioned that there are companies that are developing a retrofitting for trucks and this could be implemented universally that allows AVs to communicate with manually driven vehicles. He said his opinion that the matter should not be left to the industry, but the government should demand that after certain years on words new vehicles should be equipped with different ADAS or communication parts. (Scharfe, 2017)

Mr. Scharfe argued that all experts on the development of the AVs would agree that the vehicles need to communicate to each other as well as to the infrastructure. But, those development are left in the hands of the industry and are not regulated. And he mentioned that, at the moment, the governments are not on board, especially in V2I communication developments. There are no standards that regulate those vehicles or demand what kind of information that is communicated within the infrastructures. And Mr. Scharfe stressed that societal management or fleet management would require to be able and manage a large number of fleets of AVs. Therefore, the government needs to act in providing the standards needed to manage such vehicles. (Scharfe, 2017)

Mr. Herland also mentioned that the need for capturing the world in real time and having advanced sensors that could gather those situations. But he emphasizes that the current vehicles and sensors that are out there are capable of capturing those situations and update the data first hand. (Herland, 2018) Mr. Scharfe mentioned that the current technology is not based on GPS. It is based on scanning the environment and producing a high definition 3D maps. And it is using GPS to identify where the vehicle is and what kind of map that the vehicle need to load to perform the job. And he emphasized the need to regulate the maps. And he proclaimed that if maps are not regulated, then we will end up with each car manufacturer developing their own 3D digital map. And such way of developing is prone to error that it will probably cause accidents and cost a lot of money. However, he meant that we could change that, but it will require to bring in the government. We could use the existing data as a backbone to build the digital maps. He acknowledged that this will be costly to build but more expensive to maintain. And he agreed with Mr. Herland that the vehicles are equipped with different sensors and visual cameras to captured and maintain the maps. And he recommended that the government should make a mandate that expects the car manufacturers to take the responsibility of maintaining the maps if they want to drive in our roads. (Scharfe, 2017)

4.4.2. LEGAL INTERVENTIONS AND STRATEGIES

Mr. Herland mentioned that how fast the society or the politicians want to adapt AVs, we may need in the first generation of AVs a better separation between soft and hard mobilities. We may need separate lane. This is for AVs that could operate in the same manner as the person vehicles. But when it comes to autonomous pod buses, they could operate in mixed situations between soft and hard mobilities since they drive in slow speed. The complication of AVs implementation is more related to the speed of the vehicle. (Herland, 2018)

The primary objective of AVs is traffic safety. In AVs world there is no yellow sign, it is green or red. The vehicle will drive or stop. But, when the vehicles are mixed with the manually driven vehicles, there will be accidents from manual cars approaching from the back. Most accidents happen at the moment with vehicles that are colliding with the AVs from the rear. (Hovland, 2018) and Mr. Herland also acknowledged that we need a better knowledge in such kind of accidents and how they could be avoided. (Herland, 2018) And Mr. Hovland also supported the claim of Mr. Herland on the matter and mentioned that even WAYMO is doing a research how the AVs could adapt to the way a human is driving. And he accepted that this is the wrong way of developing AVs. (Hovland, 2018)

There are a couple of issues that the deployment of AVs need to consider such as privacy concern, vehicle safety concern and administrative concerns. By definitions an autonomous vehicle has to have everything turned on at all times otherwise the vehicle will not work. Mr. Scharfe's argument with the need for both internal and external monitoring system is not for surveillance, but for the safety and emergency situations of the passengers. (Scharfe, 2017) Moreover, Mrs. Lohne Marken and Mr. Scharfe have the same argument that surveillance should not be an obstacle. If one would not want to be monitored, they should leave their smart-phone. At the moment, even though the government is becoming very restrict on data collecting and use of data collected from a third party, we are giving the companies our consonance by accepting whenever there is an update to our mobiles without reading the changes. (Lohne Marken, 2018) (Scharfe, 2017)

New technologies have both legal and ethical challenges. The ethical dilemma of the AVs and the regulation that are proposed in other countries are mentioned in the barrier section. Mr. Scharfe recommendation to such aspects of the vehicle is that there is no situation that allows a person to choose between to evils and there should not be one for the AVs. In his opinion he recommended that the AVs should do all the necessary precautions to prevent such scenarios. (Scharfe, 2017) And Mrs. Lohne Marken mentioned that AVs should not come to a situation that they have to choose and recommended that we should not rush our way to implementing the vehicles. We should document and understand what the vehicles would do and react in every aspect of the vehicle and its reliability for a safer operation. (Lohne Marken, 2018)

Standardizing AVs is one of the challenges, but many manufacturers are using the same vendors to supply them with different equipment and parts. Even though the different OEMs are specializing in their own ways, Mr. Herland thinks that it would not hinder the implementation of AVs. The OEMs are using many common platforms which they develop and enhance their own products. (Herland, 2018) Standardizing is being done both internationally and nationally. And Mr. Scharfe mentioned that some the technological development and standardization are not only about the technical aspects, but they also have deep roots in culture. And he gave a prime example that is the pedestrian prediction. Standardizing the vehicle to predict the actions of the pedestrian whether he or she is going to cross or stay on the side is difficult. And he mentioned that studies done on the matter showed there is a lot of difference to regulations for a pedestrian's crossings from country to country. And he emphasized the need to be active in the work done in standardization of the AVs. (Scharfe, 2017) and Mr. Husøy in his opinion recommended that every situation that ends up in a legal court, should not just be standardized but also be done to law. (Husøy, 2018)

4.4.3. IMPLEMENTING STRATEGIES AND INTERVENTIONS

Strategically implementing AVs in the cities requires city and regional planners to include them in their planning. And Mr. Herland said that it is easy to lose sight of the current situations by only focusing in the future. There are a lot of ideas surrounding the development of AVs, but we need to act and plan in a realistic time-frame and idea. He recommended that city planners need to include the OEMs for developing a realistic implementation of AVs. (Herland, 2018) Further, Mr. Scharfe emphasized the need to have the communication between the city or regional planners with the industry. He stressed that if one do not know what is needed, one cannot plan. Therefore, cities and regions should have innovative partners and bring in different persons with different sets of skills. And Mr. Scharfe said that such things did not happen. (Scharfe, 2017)

> ***"The future needs people who build the law, people who build the technology and people who implement the technology to sit together and work an effective regulation and mandate."***
>
> (Scharfe, 2017)

Implementation of AVs is business incited and managing the implementation could be happen in three scenarios. These are 1) mobility services within a specific organization or sector of the public service, 2) mobility as a service mechanism within the public transport sector and 3) mobility as privately-owned vehicles. Mr. Scharfe mentioned that, Vesthimmerlands municipality in Denmark is looking all the scenarios but working with emphasis towards the first choice. They are working to implement the AVs in the municipal health sector and other public sectors. But, he acknowledged that the third choice is the one that is going to be the largest of all the three scenarios with time to come. (Scharfe, 2017)

When it comes to the way AVs are tested and the general census in the Norwegian cities and parliamentary members is that they all foresee AVs operating as a public transport mobility provider or to some extent they are allowed to drive in a car-sharing model. (Hovland, 2018) Mr. Scharfe argued that the implementation of AVs is not only about replacing a vehicle with a vehicle. It is a profound change on the way the government works, or the way the public transport is planned. Most people working with the planning of public transport will say that the main issue is the first and last mile. But Mr. Scharfe contradicts to that idea that it is not an issue when the public transport is coming once an hour or twice an hour. It is part of the problem of the whole public transport structure providing service in cities with less dense populated areas or sprawl way of living. And Mr. Scharfe also emphasized that people do not fancy or need a scheduled timetable, they need a door to door mobility. Therefore, the future should not be about integrating AVs to the existing model of public transport but rethinking of the entire public transport structure with AVs. (Scharfe, 2017)

And Mrs. Lohne Marken express the same concern as Mr. Scharfe. She mentioned the need to increase the current public transport timetable schedules if Stavanger municipality is going to provide mobility using the autonomous shuttle buses. Her argument is that using SAVs without changing the current public transport structure will not lead to people choosing the public transport specially when the weather in Rogaland is windy and rainy. And she meant that we should address all the excuses which prevents people using the public transport. And she mentioned that the plans for the SAVs in Stavanger is to be as a feeder to public transport and she stressed that we need to update the main public transport for SAVs to succeed. (Lohne Marken, 2018)

The main reason for implementing AVs is to increase traffic safety. There is a known assumption that AVs will reduce congestion. And Mr. Hovland emphasized that reducing congestion is the product of achieving traffic safety goals. And he mentioned that there would be a need to integrate AVs in a dedicated lane when their number has increased in order to maintain traffic safety. And he highlighted that the municipalities play a big role in implementing AVs. (Hovland, 2018)

Every municipality knows how they want to live or move and that is the key to implementing AVs. And the state is providing an incentive for every municipality to win a price of 100 million kroner for a city with smart ideas and smart mobility. The aim of this is to make cities and municipalities have a clear vision. Mr. Hovland also mentioned that the ideal thing that is happening now like in Finland, is the general change in the mobility paradigm with the focus in the mobility as a service scenario. To provide an affordable mobility service with AVs, he referred to an experiment done in the USA that the government had to subsidize the ticket for the first and last mile in order people to use one payment for the whole trip otherwise people would not choose to pay extra for AVs. And he mentioned that Ruter, Skyss and Kolumbus have the same plans. Using AVs as first and last mile solution to the public transport has to be a benefit not an extra cost, if you really want people to use the public transport. (Hovland, 2018)

However, Mr. Heinzerling stressed that to implement SAVs, they have to be autonomous completely. He claimed that also the vehicles are to drive autonomously, there would still be a need personal security on those vehicles in certain hours of the day or the week such as on Friday and Saturday evenings. He further understands the need for the subsidizing those vehicles, but he stressed that they could not exceed the limit threshold for the current bus subsidies. (Heinzerling, 2018)

AVs are at the hype that everyone is working to be in the forefront of the development. And municipalities that are working with the smart cities ideology now are incorporating AVs as possible solution to their plans. However, municipalities do not have the needed information about the implementation of AVs or the future road-map in their websites or their plans. And Mr. Hovland also mentioned his concern that municipalities are kind of late in providing the needed information. (Hovland, 2018)

In principle, the implementation of SAVs is not only about the mobility, but also about economic incentives. Our economic incentives should not overshadow the need for affordable, accessible and sustainable mobility. To facilitate such development requires a common view in to the different aspects of AVs in providing the community's view to the city. And such development would demand that we see the connected, autonomous and electric vehicle as part of the shared mobility service.

To integrate AVs, we need to engage the community and business on how the technology could meet the needs of the community and prepare a road-map that could guide and allow everybody with the same access to the information to further their business or encourage new start-ups. The municipality should increase the awareness of the benefits of AVs and knowledge to use AVs as first and last mile mobility services. The city should deregulate its parking requirements allowing reduced or zero parking and encourage adaptable parking garages for future re-use as residential buildings, office spaces, and retail spaces. Most cities should reexamine right of way laws within the city center and prioritize pedestrians, cyclists and public transport. (Austin City Council & Capital Metro, 2017)

4.5. SUMMARY OF POSSIBLE APPROACH TO INTEGRATE SAVs OR AVs

The development of AVs is advancing at an exponential rate, and they are expected to entirely be available in the market in the next 15 to 17 years. The development of AVs and SAVs are almost the same. The significant differences between them are the speed they operate and the functionality. To integrate SAVs or AVs has requirements which need to be in place for the safe and effective integration of those vehicles. The thesis categorized the requirements into three interconnected topics. The integration of the vehicles demands that the technical development of those vehicles and the infrastructure that supports them to be robust in their functions. The need to have a standard for the development of the vehicles and the policy and regulations needed to safeguard people from the unintended downside of the technological development.

The integration of SAVs or AVs has barriers that are related to the requirements set for the development of the vehicles and the infrastructure. The barriers have the same scope as the requirements with more diverse but intertwined themes. The barriers touch situations involving AVs and their development. They focus on the lack of information surrounding the development, the technical obstacles, the personal knowledge to use the vehicle, moral and ethical challenges, privacy and cybersecurity concerns, legal barriers and lack of information. The technological development of the vehicles is getting advanced every day. To integrate the vehicles, it is not only about the technical advancement, but mostly about the reliability of the technology. SAVs need to ensure that there is a standard mechanism for the easy usage. The vehicles need a system which avoids situations that could lead to moral or ethical decision making. Moreover, there needs to have a regulation that requires systems to protect privacy and cyber-attacks.

The vehicle development and the status of the development are kept secret by the OEMs and car manufacturers. Today, different ADAS systems are developing to aid the safe maneuvering of the vehicle, and they are getting advanced. The communication technologies V2V or V2I are part of the vehicle development that allows the vehicles to communicate to each other or the infrastructure. The communication required is not just between an AV to AV, but AV to manual driven vehicles and vice-versa. The need to communicate with the manually driven vehicles creates a challenge as the old carpark in Norway is vast with vehicles having 19 years age span among the old and the new vehicles. All interviewees agree on the need for V2V or V2I communication in all vehicles. Mr. Godal Holt further highlighted the need for the vehicles to communicate, which is an essential part of the vehicles driving autonomously to provide better mobility. (Godal Holt, 2018) However, Mr. Herland argues that the integration AVs should not depend on the vehicles communicate to each other. He proposed that the OEMs should find a means for the vehicles to drive independent of the need to communicate to each other.

The development of AVs is at its hype with everyone scoping the surface for opportunities and potentials. Everyone understands that AVs or SAVs are going to bring change, but none knows how the changes will be or how much it will change the city. There is a presumed potential, but they could also bring unintended issues. The physical infrastructure is not expected to change to integrate SAVs or AVs, but it will require constant maintenance. The roads would need to be in a standard which is acceptable to drive the vehicles safely. AVs requires further a digital infrastructure which is essential for future mobility services in the transport sector. The Vehicles requires the need to have a constant connection and to have advanced positioning systems and 3D visual maps.

Preparing standards usually proceed after the product that needs standardizing has provided service to the public. Most of the time, it is the market that dictates what to standardize. SAVs or AVs are not available to the public, which also makes the standardizing extra challenging. Internationally there are around 661 relevant ITS standards which cover some parts of the technologies used in the AVs. At the moment, no standard is mandated. Mr. Hovland mentioned that all the tech industries and OEMs are lobbying all over the world to have their standards rather than the standards provided by the ISO. (Hovland, 2018) Almost all standardization works of AVs is being conducted internationally. Norway does not have any participation on the current standardization of SAVs. Mr. Husøy further highlights that within Standard Norway, there is a deficiency of essential knowledge and experience to prepare standards. (Husøy, 2018) However, Mr. Jensen acknowledged that Norway not participating in the standardizing of SAVs or AVs could affect the national interests.

Providing regulation and developing policies is a delicate matter that needs time and complete understanding of the technology. The Vienna Convention and the UN ECE Regulation 79 describe the requirements for a driver and a steering system in a vehicle. The regulations do not allow the integration of AVs over the level 3. The development of the technology is evolving rapidly that the development complicates between what to regulate and what to standardize. Mr. Husøy recommended that a mandate should regulate every situation that ends in the legal or civil court. (Husøy, 2018) At the moment, no mandate regulate the vehicles, although some have done recommendations guidelines for developers. However, recently Norway has passed a law for the testing of the vehicles on public roads.

As Mr. Scharfe explained to facilitate the implementation of SAVs or AVs would demand the people that regulate the law, people that build the technology and people that implement the technology to work together to prepare regulations and mandate. The development of AVs could lead to the use of the vehicles in three ways. They could function in public sectors as mobility providers for employees and customers, in the public transport sector and as privately own vehicles. The business incentives surrounding the development dictates that the use of AVs as a privately own vehicle could surpass the other two functions. To achieve sustainable mobility it does not solely depend on the vehicles, but it depends on how the society want to live. How AVs function in the society is also dependent on how the society wants to move. Integrating SAVs to aid Sustainable mobility requires a significant change in land use and mobility paradigm

CHAPTER – FIVE

ANALYSIS OF SAVs IMPACT IN STAVANGER CITY CENTER

Figure 5.1- Stavanger map Source: http://nn.wikipedia.org/wiki/Stavanger_kommune

5. CHAPTER FIVE - STAVANGER CITY CENTER

5.1. URBAN STRUCTURE AND TOPOGRAPHY

Stavanger city is the administrative city of the Rogaland County with a population of 133,233 (as of third quarter of 2017), and it covers an area of around 71 km2. The city is the fourth populated city in Norway, and the Stavanger region is Norway's third largest urban region with a population of 337,687. (Statistics Norway (c), 2017) Stavanger city is found on the west side of Gandsfjordens estuary and the islands north of the bay. The city boundaries were expanded in 1965 when all Madla area and west of Gandsfjordens bay of Hetland were included. The city now bounds with Sandnes to the south, Sola in the south-west, Randaberg in the northwest and Rennesøy of Åmæy to the north. (Geir Thorsnæs, Stavanger, 2017)

The city of Stavanger is divided into seven boroughs: Hundvåg, Tasta, Eiganes and Våland, Madla, Storhaug, Hillevåg, and Hinna. And also, from 01/01/2020 the municipalities of

Figure 5.2 – Stavanger City Center (Own figure)

Stavanger, Finnøy, and Rennesøy would be joined to form a new Stavanger municipality. (Stavanger Municipality (a), n/d) Stavanger is a major focal point, with different road infrastructures and several boat connections to the north direction Ryfylke and Haugesundshalvøya. And Sola international airport (Stavanger Airport) is 13 km to the southwest of the city center.

Stavanger City Center is located at Vågen to the north of Breiavatnet lake and the railway station expanding up to Johannesparken to the east and Bjergsted Kulturpark to the northwest of the city. Stavanger city center is composed of the three boroughs Storhaug, Eiganes, and Våland. The city center is built around the middle age time, with older wooden houses, narrow roads, and charming streets. Kirkegata is one of the main business streets in the city. Domkirken is one of the oldest cathedrals that is best preserved medieval building. It is one of the oldest churches in Norway built in around 1100 – 1150. And new developments on surrounding of the old city mainly around Torget have changed how the city looks. (Geir Thorsnæs, Stavanger, 2017)

5.2. HOW THE SOCIETY WANT TO LIVE

Shared Autonomous Vehicles are a new technological development within mobility, and they are one part of a puzzle in the spectrum of smart mobility. They have a vast potential to transform land use and transportation systems within the urban built environment or the city. Their potential is dependent on how the society use them. They could disrupt the transport infrastructure or make public transport more efficient.

In general, Norway is working on transforming the mobility paradigm to sustainable mobility with a focus on pedestrians, cyclists and public transport. The government introduces competition for all cities and counties to think smart and integrate technological development to enhance public transport. (Olsen, 2018)

Every transport infrastructure has its challenges with the way the city regulates the land use. Stavanger was built in a polycentric model where there is a segregation between commercial areas, residential areas, and public service areas. (Næss, Peters, Stefansdottir, & Strand, 2018) The development of Stavanger was based on personal car-dependent mobility paradigm which promoted sprawl way of living. The developments in Forus and Ullandhaug area are results of such developments. Forus was developed as commercial, and business area and Ullandhaug area is center for the University of Stavanger and future home to Stavanger University Hospital. Such developments impose traffic management demand, and also they take people away from the city center.

At the moment, Stavanger municipality is working to redirect its car dependency with a substantial change in mobility paradigm based on public transport, cycling and walking. So the municipality has signed the urban development agreement "Byvekstavtaler" with the state. The municipality has introduced road tariffs which will be effective from August 2018 to reduce vehicle kilometer travel VKT and reduce congestion. The municipality has introduced a city package program "Bussveien" that focuses for a better flow of public transport. The municipality has four main public transport routes that stretch from the city center to the boroughs of Stavanger. Those routes make the basis for the future development strategies and plan to densification alongside the route's axis. (Stavanger Municipality, 2016)

The primary goals of Stavanger municipality are to make Stavanger city center as the county's most important city center and be on icon that is built on sustainable development. (Stavanger Municipality, 2016) The municipality has developed a municipal sector plan for the city center, and the documents also have proposals to redevelop harbor front and Stavanger central station.

Stavanger city center is not geographically placed at the center of the municipality or the county and recent development and activities in Forus and Ullandhaug the university area have affected the development of the city. The city center has a demand for commercial spaces. Analysis of the city done in 2016 shows that there is a need for office spaces, retail stores and dining venues on the ground floor with the opportunity for a beer garden. (Stavanger Municipality, 2014)

Stavanger City Center has low densification when compared to other cities such as Oslo. Moreover, the city has many areas which are not fully utilized or used as a parking area or storage area. The city has now recognized that the need to increase the number of workplaces, residential buildings and service areas. There have been different views with regard to how the city development is proposed and what kind of building masses that need to build. And some of the people with a critical point of view had their reasons based on the increase in traffic with new development and the size of the area proposed with the potential for development. (Stavanger Municipality, 2018) The future development of Stavanger city center has had different views. Old regulation plans had plans that focuses on the development of the city center in cultural perspective and the new regulations protects the area from several urban development considerations. (Stavanger Municipality, 2016)

Today the public transport is structured to have a fixed route and scheduled timetable. Moreover, Rogaland county is subsidizing Kolumbus (the public transport provider) for about 800 million kroner each year to keep services on the scheduled timetable. (Heinzerling, 2018) And the people using public transport buses only account for 8 % of all the travel. The situation is that we are using a lot of money and resource for large buses to travel on schedule with no or few passengers. And transforming our transport infrastructure with new model that exploits the advantages of SAVs to our city would provide a better mobility to the people and use public money efficiently. They also bring a new category of public transport users who were car users.

The county has taken a strong measure to reduce the personal vehicle travel with a prohibitive road tariff with prices 22 and 44 kroner for crossings in normal time and rush-hour crossings respectively. (Rogaland County, n/a) The prices could seem hopeless for people who think the public transport is not reliable or efficient. The measures This could be considered as the "stick" of a stick and carrot method with the county's strong stand measures.

Here, the integration of SAVs in the public transport has the potential to be the “carrot” of such actions but also the actions could also facilitate the integration of SAVs.

Perspectives and critics are always dependent on which criteria do we develop the city and the kind of mobility paradigm we intend to use. Moreover, what we know is only the past. We design our cities with the infrastructure of yesterday and anticipate solving future problems with the same procedures. However, change is coming, and we do not know the change. New technological developments and SAVs could provide a means to change our mobility paradigm. SAVs could be a means that strengths the comfortability, accessibility and afford-ability of public transport. Changes on the transport infrastructure could have an impact to the built environment.

5.3. THE IMPACT OF SAVs ON STAVANGER CITY CENTER

The area in a built urban city center is of great value economically and socially to the municipality as well as to the society. The integration of SAVs is poised to transform the city in different ways. First and foremost, all presumed potential of SAVs is that they will free areas which were reserved for the car. Freeing of those areas opens an opportunity for development. The development within Stavanger city center has had different views on how the future development should be. Early regulations were saying that the medieval buildings should be redeveloped with new buildings and the current regulations saying that they should be preserved of historical value. Moreover, most of the time, the plans are regulated with a compromised action between keeping the historical identity and modernizing. The most challenging of such development is finding an area for development.

The integration of SAVs in Stavanger City Center could have a significant effect on the built environment. Although we know that SAVs will impact the city, we do not know how it will impact the city or how much the impact will affect the city center. The impacts, not all, presumably would change parking areas requirements and the road structures. Those two impacts are most agreeable aspects of SAVs integration. The effect of the changes could create a possibility of densifying the city center. Furthermore, they could allow us to create an attractive urban area and living environment with much-improved quality, and accessibility.

5.3.1. IMPACT ON PARKING AREAS

The need for parking in the era of SAVs is exceptionally negligible as the vehicles do not require to park or search for parking. The SAVs would always be in search of a new customer, and they will mostly be in motion. They could considerably reduce the number of parking areas within the city center. Stavanger city center has around 8500 p-places that were registered in the municipality, in which 55% (4700) are available as public parking areas while 45% (3800) are registered as private parking areas, and not all the private parking areas are registered. (Stavanger Municipality, 2014) Figure 5.3 shows some of the public parking areas. The dark brown shaded areas are representing parking buildings, and light brown represents areas with parking on the ground floor, and the brown ones are roadside parking areas. Those marked areas on the figure almost make half of the total registered parking areas in the municipality.

The marked areas on the figure have a total capacity of 3,390 parking places. They make 40% of the total registered parking in the city center. The regulated area needed for a parking place for a personal car is 20m2 per car on surface or in-house parking and 10 m2 per car with an open area of 3m2 after every second car. (Staten Vegvesen, n/a) The car parking on the shaded areas have occupied an area of 65,650 m2. The area collectively is as large as the size of almost 7 football fields. The calculation has not taken into consideration the space needed for pedestrian walking area or vehicles runway from and to the parking area on surface parking or in-house parking. The names and parking sizes of the different shaded areas are shown in Appendix A.1.

Figure 5.3 – Public parking Areas in Stavanger City Center (Own figure)

Stavanger municipality had planned the need for restrictive measures in parking norms in its initial plan for the city center in 2016. The new policy also recognizes the need for some reforms in the parking areas to achieve a zero growth in VKT within the city. The municipality recommends different plans to reduce the number of car parking or manage car parking in the city. (Stavanger Municipality, 2018)

SAVs have a potential to reduce the need for parking in the Stavanger city center. The future could be that we do not need utterly parking area within the city center. On conditions that there are manually driven cars and the municipality do not introduce car-free city center paradigm partially or entirely, the municipality could not restrict all car parking completely. However, it needs a transition mechanism to reduce the car parking. In this thesis, I intend to see three locations in which SAVs could have an impact in the city center. The reasons for choosing the three locations is that the locations have a potential for future development, to free as much as possible parking areas, creating attractiveness to the city and the possible availability of mobility with SAVs to access the area. The locations I have chosen are Stavanger Station, Vågen, and Holmen. The municipality has already recognized the potential in those areas and had plans which are sent for consultation. The plans, however, are done with a compromise for relocated parking areas to other locations.

A. Stavanger Station

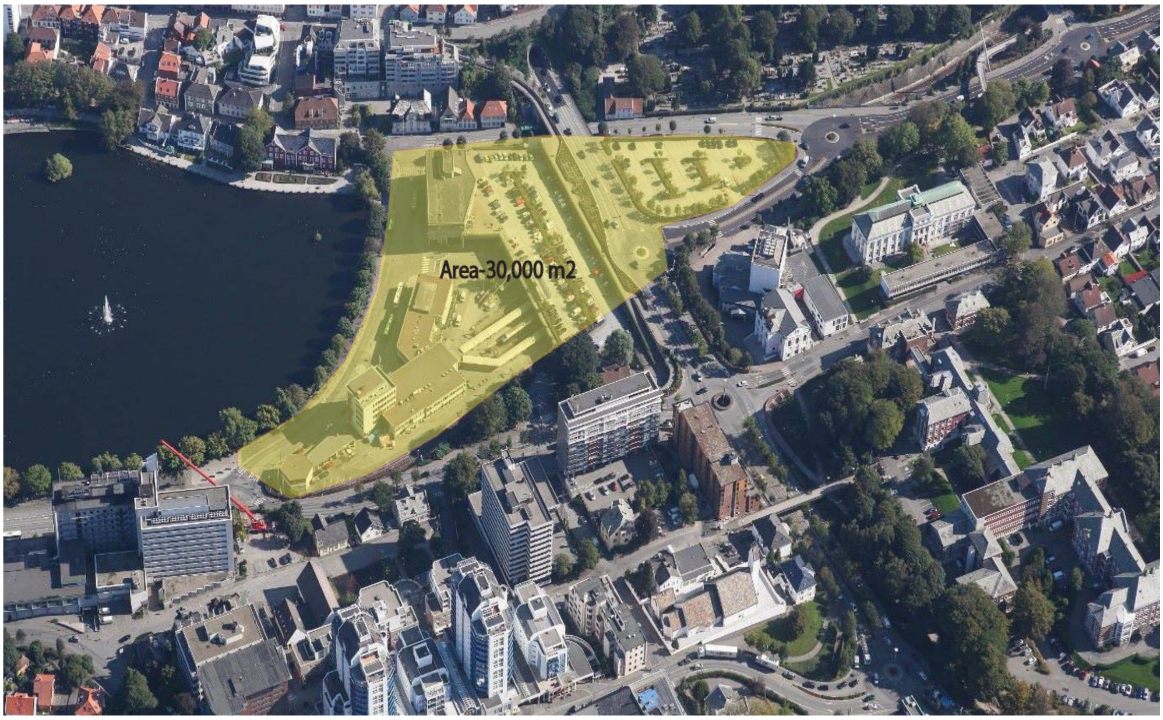

Figure 5.4 – Stavanger Station (map taken from 1881.no/kart)

The integration of SAVs could help free up a space used for car parking. The parking area P-Jernbanen has the capacity of 500 cars with the parking area around 10000 m2. At the moment, Stavanger station is used as train and bus station, and car parking. The area also has other parking buildings and surface parking locations of the same size as the P-Jernbanen. The surrounding parking locations have used almost an area 11000m2 as parking. Removing the parking area at P-Jernbanen should not be a challenge that the need for parking in the transition time could be relocated to the parking house at St. Olav.

Figure 5.4 shows the area designated to Stavanger station and the parking areas available around the station. The yellow shaded area has an area of 30000 m2. The parking area designated at the moment have one-third of the total area. As the ratio shows the parking size designated to parking has no merit when compared to the situations with large cities central stations such as Oslo central station.

However, the situation at the station is that local buses are stationed around lake Breiavatnet. Removing the parking in the area could facilitate the re-developing of the central station as a modern building with all the services are under the same roof. The integration of SAVs could facilitate the challenges that could arise with the need for parking. However, the potential of removing parking in the station should not base on the introduction of SAVs. The area is a strategic area with many unused potentials especially the area around lake Breiavatnet.

The municipality is working in redeveloping the station to be a smart hub which has many workplaces and a better public place. (Stavanger Municipality, 2018) There is also a consultation going on to move the Rogaland theater to a new location at Bekhuskaien which reduces the need for parking.

The situation with the local buses stationed all over the place distorts the beauty of the area. In the assessment of the area, the plans should include a common transit place for all types of modes in a closed system including future drop-off or pick-up depot center for SAVs. Further, the plans should include a depot center for delivery trucks as the AVs could be used to deliver goods within the city center. The development of this area is essential with or without the integration of SAVs, but SAVs could make the development of the area more people-centric.

B. Holmen

Figure 5.5 – Holmen (map taken from 1881.no/kart)

Holmen is also one of the locations which the municipality have identified as a significant development location which could balance the urban development within the city center. (Stavanger Municipality, 2018) The introduction of SAVs in the city center could allow the removing of all parking area in Holmen. Redeveloping Holmen as a car-free area with better structures and publicly accessible waterfront could create a tremendous potential to be an attractive area. As of today, there is no decent public space where people could sit or have a family picnic without the distraction of cars moving in and out of parking areas or cars searching for parking.

Figure 5.5 shows the area dedicated to car parking at Holmen. The yellow shaded areas in the figure make up around 20,000 m2. There is not a single building in the area except for Oljemuseum and a playground Geoparken. In the new plans, parking house Jorenholmen is proposed to be relocated to Fiskepiren. The municipality is working to redevelop the area. In the assessment of the area, the municipality should consider developing the area as a car-free area which prioritizes pedestrian, and cyclists and public transport. Moreover, It has a potential to be a test site for the integration of SAVs in the start phase.

Figure 5.6 – Parking areas at Holmen (own figure,2018)

Figure 5.6 shows some of the parking areas at Holmen. The figure shows parking areas at Jorenholmen, Geoparken, Oskars plass and Ryfylkekaien. The situation in the area is that there are more parking designated areas than there are restaurants or other service provider buildings. Moreover, the parking areas are killing the fabric of the area to be an attractive and more people friendly area.

C. Vågen / Torget

Vågen is a cove of Byfjorden in the city of Stavanger. The area is one of the most visited areas in Stavanger city center. The area is highly trafficked, and the critical parts of the area are designated for parking. The area is used to its potential in public holidays such as 17th May and when there are festivals in the summer. In such occasions, the parking areas are used for outdoor services and street food.

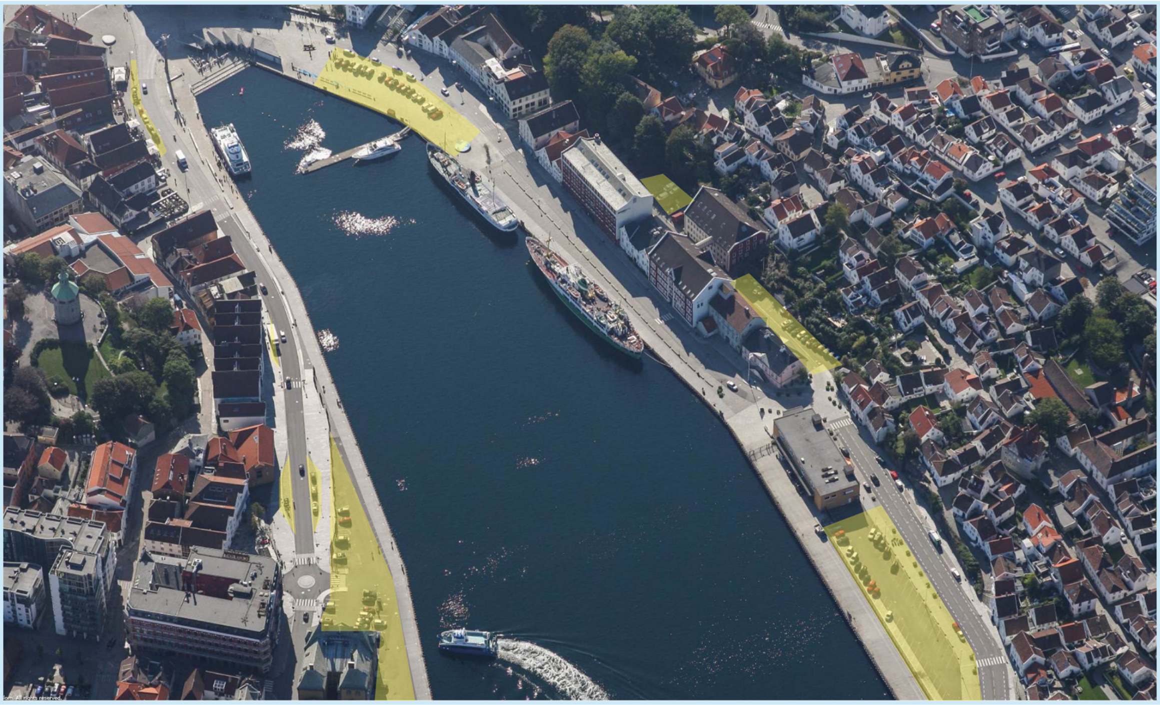

Figure 5.7 – Vågen/ Torget (map taken from 1881.no/kart)

Figure 5.8 – Vågen/ Torget (map taken from 1881.no/kart)

SAVs introduction in the city center could eliminate the need for parking in the area. So the parking areas could be used for other purposes. The figures 5.7 and 5.8 show the areas designated for parking at Vågen. The yellow shaded parts in the figure designated to parking have an area of around 13 000m2. Moreover, SAVs could provide the mobility service in the area that parking necessities could be negligible.

Figure 5.9 shows the situation on Vågen. The area is dominated cars and most of the area is designated to parking. The figure is divided by two colors to show the contrast of the streets. The red bounded figures show the street at Skagenkaien and the green bounded refers to the street at Strandkaien. The streets differ in the functions of the buildings at the street give. The buildings at Skagenkaien are mostly restaurants and hotels which has beer garden in them while the buildings at Strandkaien are mostly museums and offices. Removing the parking at both streets would open new opportunities and would make the waterfront available for the public. The area is now affiliated only to cars.

Figure 5.9– The parking situation at Vågen - Stavanger City center (own figure)

The impact SAVs could have in Stavanger city center is that they would provide easy access and better mobility services to the areas which could facilitate the removal of parking areas. There could be an argument that there will be a need for parking as long as the manually driven vehicles are allowed to drive in the city center. The compromise to such argument should not come at the expense of the city's development and functionality. The municipality should remove all surface parking in the city center and allow decisive parking buildings to function as public parking buildings. However, the decisions to remove the parking areas should not base solely in the integration of SAVs. The municipality should revise the parking requirements in the city center.

5.3.2. IMPACT ON THE TRANSPORT INFRASTRUCTURE

SAVs have a potential to disrupt the whole transport infrastructure. The impact they initiate provides new challenges and presents solutions to the existing problems. They have a potential to improve accessibility and change the road infrastructures. SAVs integration as a feeder to the public transport in a “Mobility As A Service” paradigm opens vast opportunities within the public transport sector. The public transport infrastructure could not solve the current problems of congestion, traffic safety, air and sound pollution, and demand for new infrastructure with an increase in mobility demand. The municipalities could not persuade people to give up their cars for the public transport. People experience public transport as unreliable and uncomfortable. Also, such reasoning has been in Stavanger municipality. People think that the public transport does not suit in their way of life. The whole experience starting from when they are on the way to the bus station, waiting in the bus station in a windy and rainy day, their experience in the bus, and the situation from the bus to their destination sums up as a not desirable experience and time-consuming. (Lohne Marken, 2018)

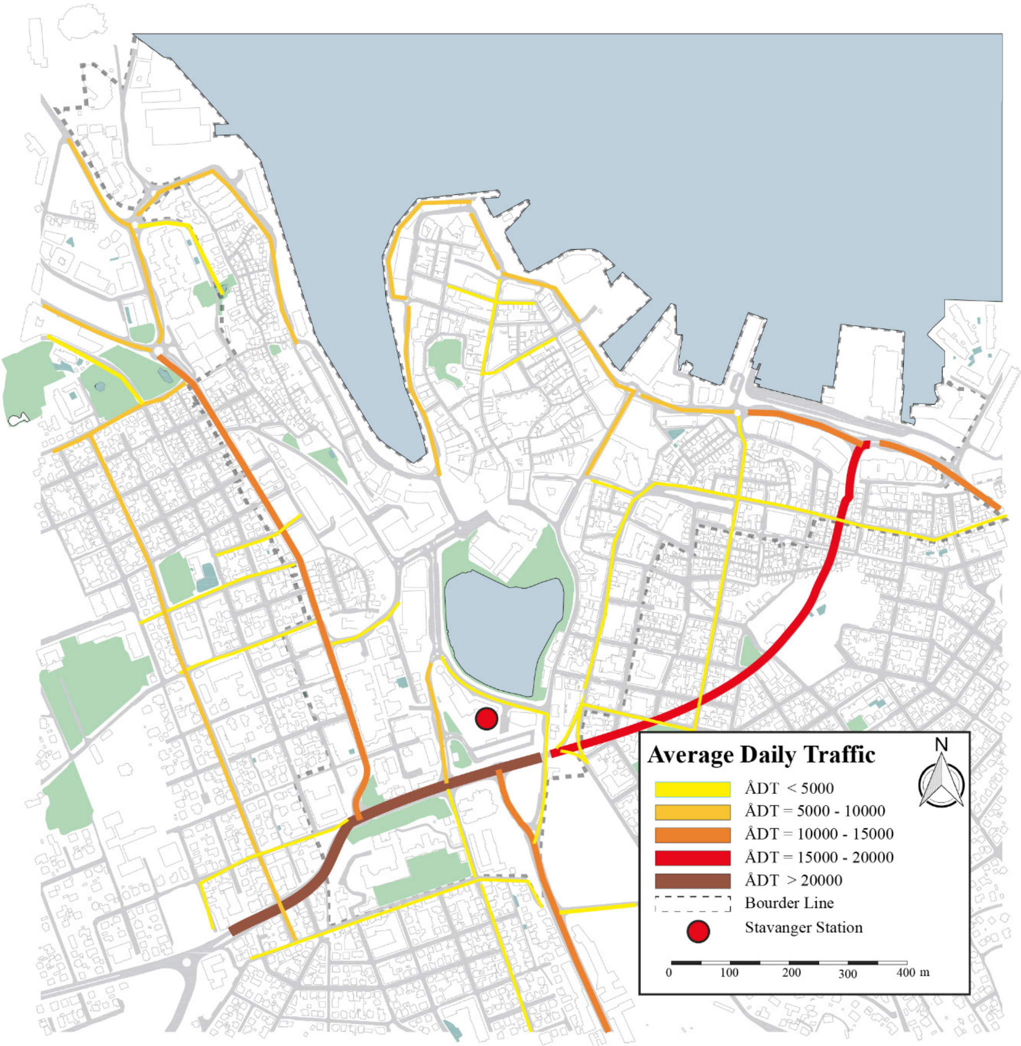

Figure 5.10 – Average Daily Traffic at Stavanger city center (Data collected frm NVDB, own figure)

The integration of SAVs has a potential to change peoples experience and the perceived reputation of the public transport in Stavanger municipality. They also could reduce the congestion, and increase traffic safety. Sound pollution is dependent on reducing the number of vehicles which also corresponds to the congestion problem. Air pollution is mostly dependent on the vehicles becoming electric vehicles than autonomous vehicles, but the expectation of the SAVs been an electric car is considered as a must for such vehicles in Norway. Also, Norway produces most of its electricity from a renewable source that indirectly correlates SAVs in helping reduce the air pollution.

Figure 5.10 shows the average daily traffic in Stavanger city center. The thesis considers the same locations as mentioned in the section 5.3.1 to keep the contrast on the role of SAVs. The roads bounding the locations are highly trafficked. The roads bounding Stavanger station are the most trafficked roads with Bergelandsbrua having 26,200 Average Daily Traffic (ADT) and Olav Vs Gate having 6000 ADT. The street starting from Østervågkaien to Skansegata bounding Holmen is also highly trafficked with ADT of around 8000. The

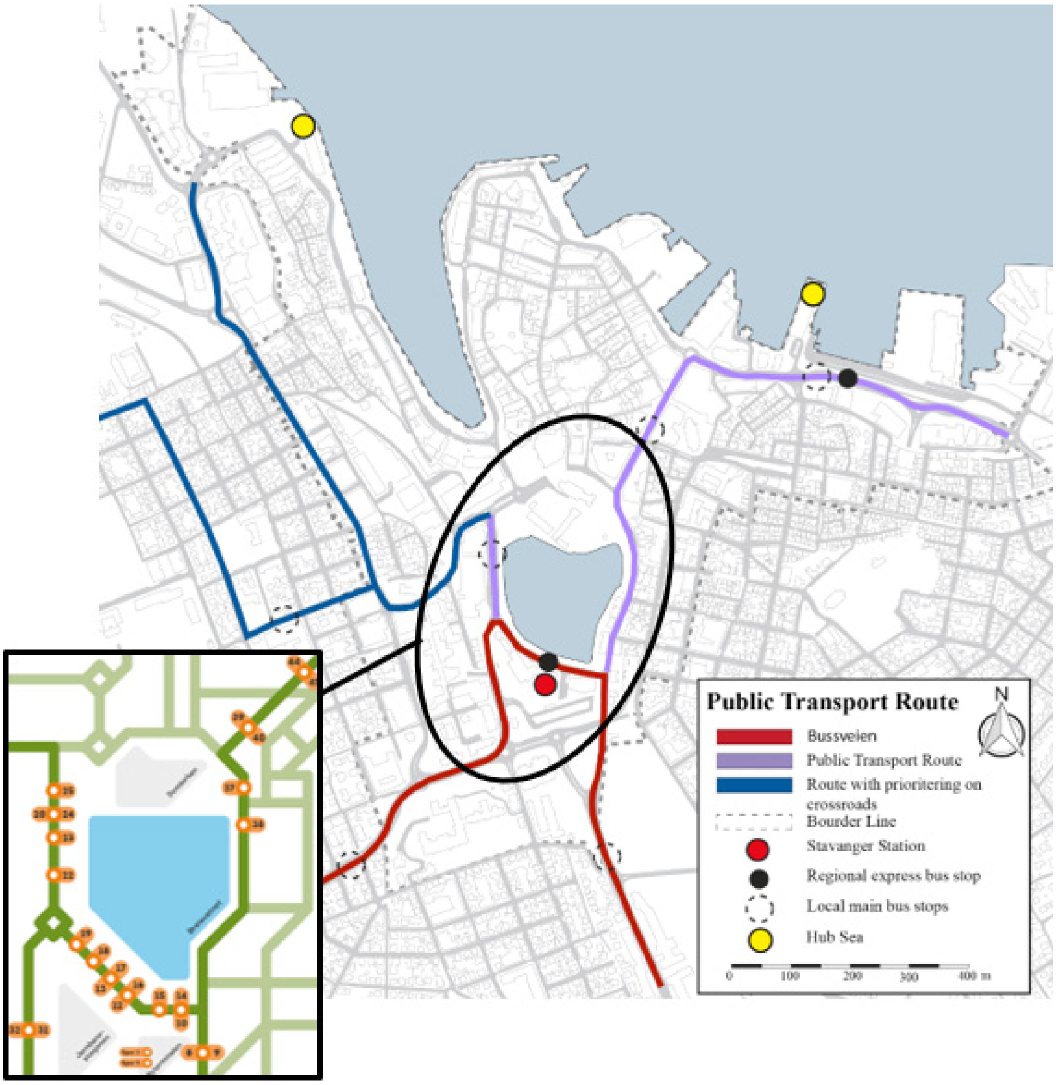

Figure 5.11 – Public Transport Routes at Stavanger city center (Data collected from Kolumbus, own figure)

streets bounding Vågen do not have a complete statistics for the whole route, however, streets Skagenkaien and Nedre Strandgate (start and end of the route) have ADT around 8000. (NVDB, 2018)

SAVs could reduce the ADT tremendously in the streets that could also help people which have to drive into the city center and change the experience and conditions for pedestrians and cyclists. The construction of the new tunnels Ryfast and Eiganestunnel could also help reduce the ADT in the Bergelandsbrua and Løkkeveien that could aid in restructuring the public transport routes and the redeveloping of Stavanger station. Introducing measures to reduce ADT in those areas is not a prerogative impact of SAVs. They could provide alternative mobility to the area which could aid politicians and planners in their decision making and provide regulations with measures to restrict vehicles in those areas.

The integration of SAVs could arise challenges in restructuring for the whole transport infrastructure. SAVs to function as a first and last mile part of the public transport would require that we need to re-structure the boroughs of Stavanger as a hub with fast routes for public transport. So the existing fixed routes of the public transport which serpentines to reach deferent locations at a single trip need to be updated and the time needed to move from a borough to borough could be reduced. SAVs then could manage the mobility within each borough from the hubs.

Figure 5.11 shows the existing routes of public transport in Stavanger city center. The routes divert in four directions. The figure also shows the routes with all the local bus stops surrounding the lake Breiavatnet. At the moment, buses cross through the city center. As a result, buses that use the route through Klubbgata disrupts the area with their size and the number of buses passing through the route as the time intervals of their schedules are interlocked to each other to make transit possible. Such situations are observed in figure 5.12. The figure shows the situation on the street Klubbgata at round two in the afternoon.

Figure 5.12 – Traffic situation at Klubbgata in Stavanger city center(own figure,2018)

The road is highly trafficked road with 8500 ADT. And the figure just only shows partial description of the hole picture.

The municipality has plans to close the Klubbgata for personal vehicles in the new section plan for the city center which could reduce the congestion in that route and allow the buses to pass efficiently. SAVs integration in the city center could allow the removal of large buses in the city center freeing up roads dimensioned for such vehicles. SAVs could impose challenges to restructure the public transport routes and the development of Stavanger station to maneuver the buses in a coherent pattern without entering to the city center.

SAVs creates also challenges to how to manage the interaction with pedestrians and cyclists. Traffic safety is one of the primary goals of SAVs. In order SAVs to maneuver safely, they need to drive at a slow speed as in dense areas. Stavanger city center has in most of

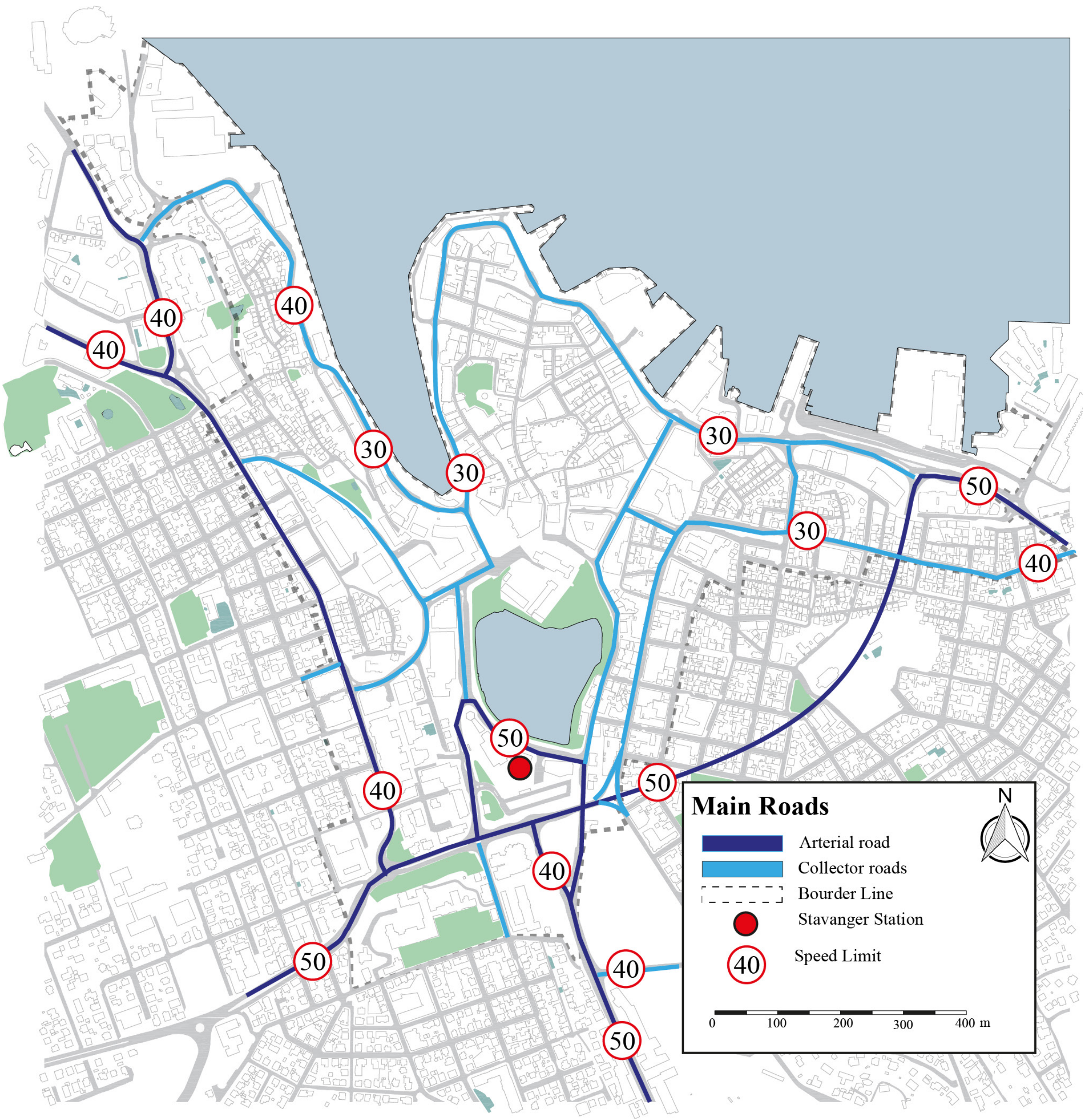

Figure 5.13 – Speed limit at Stavanger city center (Data collected from NVDB, own figure)

its roads a speed limit of 30 km/h and pedestrian streets inside the periphery of medieval buildings as shown in the figure 5.13. Thus, the situation makes the integration of SAVs in the city center actual and their interaction with pedestrians and cyclists safe.

The integration of SAVs in the city center could provide opportunities to change the road structures in the city center. Stavanger city center is distressed by the flow of vehicles searching for parking or vehicles crossing through the city center. Integrating SAVs in the current situation could be complicated or even difficult to achieve. Moreover, strong measures in parking reduction and restricting access for personal vehicles could relieve the burden of the city center. Some of the interviewees had suggested that in the start phase SAVs need to be allowed in a dedicated lane to create a safe transition period. Such ideas could be applicable in Stavanger city center as the municipality has applied the same alternative to facilitate the "Bussveien" project.

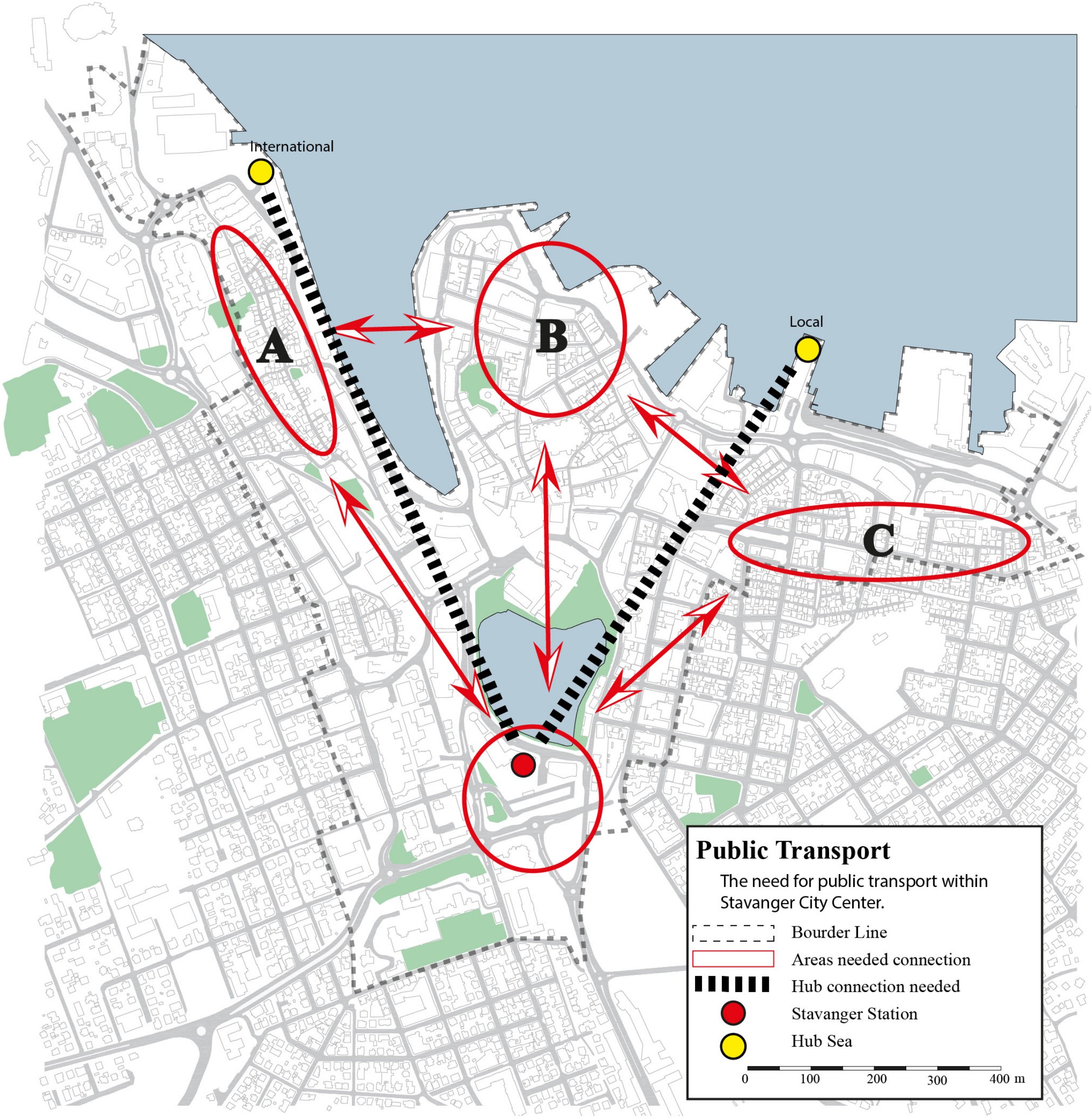

Figure 5.14 – Accessibility and connection between different sectors of Stavanger city center(own figure,2018)

In general, SAVs could change the road structure removing the roadside parking, reducing the road width and changing junctions. The current designs standards of roads we have are more favorable to the vehicles. The possible change of the road structures is shown in figure 3.1 in the theory chapter. Although the figure shows a general potential for the changes in the roads, the same changes could apply in Stavanger city center. The streets Kongsgata, Klubbgata, Havberingen, Skansekaien, and Strandkaien, are some of the strategic streets with massive potential for the beer garden and outdoor services.

Another potential impact of SAVs in the Stavanger city center is the ability to provide accessibility to all parts of the city as part of the public transport. The location designated in A, B, and C in the figure 5.14 is on average 1km away from Stavanger Station. Those locations at the moment are not connected with the public transport directly. Locations A and C could be accessed by the public transport at streets Løkkeveien and Verksalmenningen, but location B (Holmen) do not have any scheduled bus.

Those areas are supposed to be covered by the public transport designated to the areas Storhoug, Våland, Eiganes, and Byhaugen. Kolumbus has assigned buses with numbers 11,12, 13, and 14. However, the public transport services to those boroughs are not sufficiently scheduled. They have the bus on time schedules with a weekend service once an hour and twice an hour in the weekdays. Moreover, they do not pass through the most populated part of those areas. (Kolumbus, 2017)

People, however, do not come to the city center to take the bus or the train. They come to the city center for shopping, luxury, or work. Sometimes, they could have packages or stroller with them that makes leaving the car an impossible scenario. However, the potential of SAVs could also allow people to travel from their places to their destination directly within the city center.

The deployment of the SAVs could impact the boroughs bordering the city center. At the moment, they get public transport on scheduled service on specific hours. And, most of the time the buses only carry few people on their trips. SAVs could provide service to those locations on demand without being restricted to a specific day of the week or time of the day. They could also be used as a feeder to the public buses at Stavanger station or other future hubs that are closest to the place. The impact of SAVs on providing accessibility has a massive role in changing how the city function. The changes also play a prominent role in transforming the attractiveness of the city.

5.3.3. IMPACT ON THE ATTRACTIVENESS AND LIVABILITY OF STAVANGER CITY CENTER

SAVs have a considerable potential to transform Stavanger city center. The impact of SAVs in parking areas and the changes in the transport infrastructure imposes significantly in improving the attractiveness and livability of the city center. Although the size and architectural design of the vehicles could have a role in how people perceive the city, it is the area freed from the cars that could transform the city in its functions and densification. The presumed potential role of SAVs is abundant compared to the experience and conditions for pedestrians and cyclists and car users at the moment.

Figure 5.15 – People crossing the road at Torget in Stavanger city center (own figure,2018)

The cars put pressure on pedestrians and cyclists making them insecure while walking or riding along the side of the road or crossing the road. The cars have the right of way in almost all roads in Stavanger city center reducing pedestrian crossings at junctions. Moreover, pedestrians do not have the luxury of relaxing while crossing the road as shown the figure 5. 15. They are always on the look or are insecure especially if they have small children. Also, in other situations, they are forced to J-walk the streets as shown in figure 5.16. The figures are taken at Haakon VIIs gate and Klubbgata respectively. The situation at Klubbgata is more critical to traffic safety. Young people and children wanting to cross to the Arkaden mall are computing to cross the road before the next vehicle comes. In the last ten years, there had been nine accidents involving pedestrian crossing the road on that street. (NVDB, 2018)

There are different locations in the city center with the same situation as the Klubbgata street. Integrating SAVs in the city could change the right of way form a car based system to a pedestrian or people-centric road system. It could further allow pedestrians and people to use the roads with the same affiliation as vehicles do. The situation at the moment is that people are restricted to a width which is less than one-third of the road size designated for cars.

Figure 5.16 – People J-walking at Klubbgata in Stavanger city center(own figure,2018)

Figure 5.17 shows students playing a choreographed dance and are restricted to the sidewalk as the road is highly trafficked. The occasions and events which highlights the beauty of the city were hidden as a background event to a car dominated streets. People sitting on the roadside for a cup of coffee are blindsided to not feel or enjoy the city on a beautiful weather day.

Figure 5.17 – Girls performing choreographed dance at Klubbgata in Stavanger city center(own figure, 2018)

Figure 5.18 – Situation on the streets at Stavanger city center(own figure,2018)

The streets shown in figure 5.18 are some of the main collector roads. The integration of SAVs could impact those streets enormously by freeing areas held for parking and reducing the number of vehicles going through those area. The potential for those areas is to be an attraction places and bring people to the city. To succeed at such quest needs sufficient space for activities, and events not restricted on occasions and seasons. And SAVs could facilitate mobility and provide the surplus areas held by the existing vehicles. However, change is needed in those areas and the city center in general. The integration of SAVs could facilitate those areas to function in the same standards as Aker Brygge in Oslo. Moreover, the streets lack greenery which kind of makes the area plain, sad and not attractive. SAVs could free up space for a variety of purposes in the streets that could transform the city.

Changing the attractiveness of Stavanger city center do not solely rest on the shoulders of SAVs. Although they could utilize the means to get rid of the cars away from the streets, the change is dependent on the way we want to live or move. The beauty of a city is not the buildings or the infrastructure but the people and the services that make people want to visit again. The potential of SAVs freeing areas could allow people to move freely and create more public spaces with essential services. Such possibilities would change how the city function and how the society perceives it. Besides, SAVs have a substantial economic and technological innovation potential, which could incite new business models and work opportunities. In this transition phase, building the future with SAVs in mind could make Stavanger city center a tourist attraction area and center for innovation.

5.4. POTENTIAL IMPLEMENTATION OF SAVs IN STAVANGER CITY CENTER

Stavanger city center is a medieval city with narrow roads and curbstone paved streets. The integration of SAVs has many requirements on both the vehicle and the infrastructure as discussed in chapter 4. When investigating the possible implementation of SAVs in the city center, the assumption is that both the vehicle technology and the infrastructure needed to drive those vehicles is ready to be implemented. However, in the case of Stavanger city center, there need to consider the width of the roads. Finding the applicable road or designating a specific road is necessary for the vehicle to reach the desired destination without disturbing the mobility pattern of the pedestrians and cyclists. Secondly, the routes also need to include as much as possible all dense areas and the streets which the municipality has designated as active ground floors. Implementing SAVs requires also finding an applicable system where the system meets the needs of the users.

5.4.1. VIABLE DEPLOYMENT SYSTEM

Implementing SAVs to achieve a better and more efficient transport could be done in two alternatives as mentioned in figure 1.4. Alternative one (computing with the traditional public transport) brings many concerns with using the public transport efficiently as mentioned at the start of the thesis. However, if SAVs achieved their presumed potential of providing mobility to everyone, alternative one could be applicable in areas where there is a sprawling way of living. The alternative has a similar function as car sharing but with few more seats. Although alternative one provides potential implementation scenarios, the thesis will not pursue the alternative.

The thesis investigated the implementation scenarios of Alternative two (As an integrated part of the traditional public transport). The alternative has two scenarios. The scenarios emphasize the possible functional mechanisms of SAVs to facilitate the effectiveness of the public transport. SAVs could function as “scheduled mobility” providers or as “demand generated mobility” providers.

A. Scheduled Mobility – SAVs functioning as scheduled mobility could provide mobility with no restrictions and obligations for the users. It could allow mobility to people with reduced knowledge of using an electronic app to order travel. It could also aid the city in managing the number of vehicles that circulate the city center. Sustainable mobility also focuses on the social sustainability of the society to have better health. SAVs deployed as scheduled mobility could aid achieve the goals. It could allow people with the ability to use other sustainable mobility modes such as walking and cycling not to be dependent on SAVs in all their trips.

B. Demand Generated Mobility – SAVs deployed a demand generated mobility could provide mobility at peoples request. They could reduce the waiting time for people and add efficiency to the mobility services in areas with reduced activities such as residential buildings. They also provide people with the ability to plan their travel. SAVs functioning as demand generated could allow service providers with an overview of the trips generated to enhance services further.

Both scenarios have potential to succeed in the city center. They have their strength and weakness dependent on the circumstance they are deployed and the locations they serve. To choose one of the scenarios which could function in the whole city center and potentially surrounding boroughs would not aid in sustaining the system and supersede the car. Hence, the thesis has chosen to create a new scenario with SAVs deployed in a "Mixed Mobility" of both scheduled mobility and demand generated mobility.

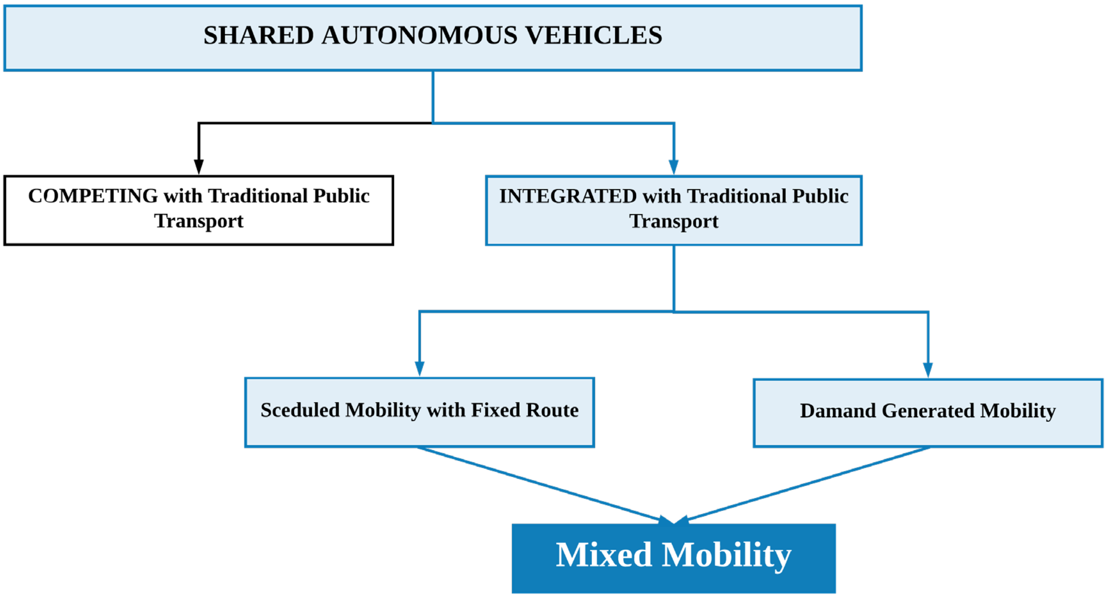

Figure 5.19 – Selecting Mobility System (own figure,2018)

5.4.2. MIXED MOBILITY AND SELECTING THE ROUTES

Mixed mobility could allow the city center to have a more reliable and people-oriented mobility system. It could allow the use of scheduled mobility in areas where the activities on the streets discard the use of cars and accessibility to the area is more achievable with walking and cycling. It could also allow the use of demand generated mobility in areas where SAVs deployed as scheduled mobility are less effective and trip generated is low. The scenario could aid achieve the mobility needs of all people whether they have access and ability to order the trip beforehand or they follow the scheduled timetable.

Deploying SAVs in Stavanger city center would demand to analyze the possible route that the vehicles could drive without changing the fabric of the city. The mixed mobility system could be deployed in three alternative routes. One is "No Route" that the vehicles could float around the city. It is the destination of the user that dictates the route and endpoint of the route. Second is a "Base Route with a possible extension." The vehicles have a predefined base that restricts how far the vehicle can go. It also has a semi-defined route with possible extensions. The third one is " A full route with the base route and extensions." The route includes both predefined base routes and a free-floating routing system with extensions. This system is location defined. The base route is dedicated to a specific area, and the free-floating is dedicated to residential areas. The extensions will allow people with limited ability to move could get the desired service.

Out of all three choices, the Full Route with a base route and extensions is more applicable to the mixed mobility system. Both systems are compatible with each other that could facilitate the effectiveness of SAVs in aiding the transit system with the public transport. Allowing people to coordinate their trips and simplify their daily activities could lead to more people choosing the public transport. The changes that could happen in the city center could also affect the boroughs of the city, and the public transport needs to be restructured to increase the effectiveness and frequency of the trips.

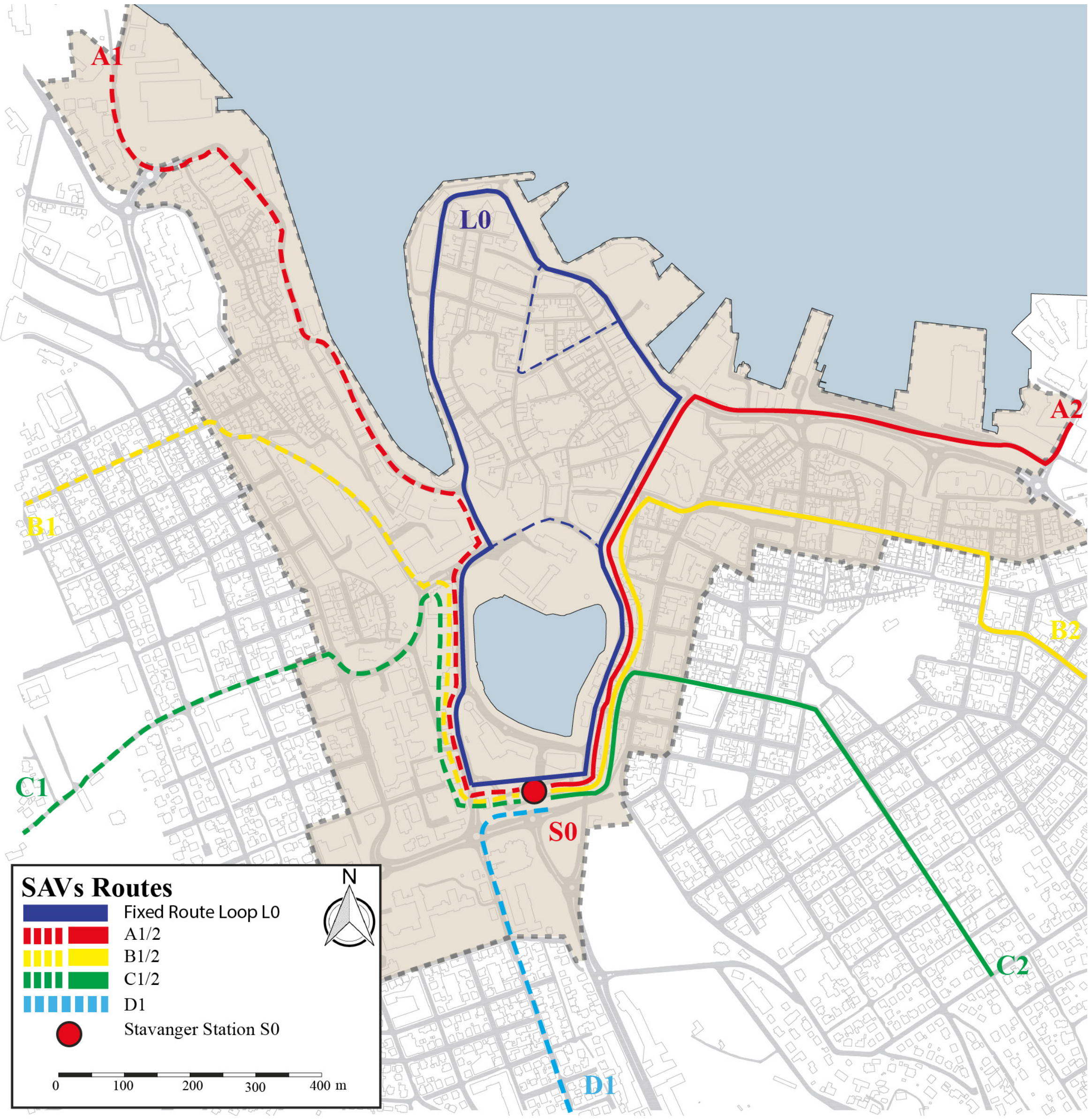

Figure 5.20 – Potential SAVs routes at Stavanger city center(own figure,2018)

The thesis has proposed potential routes in the city center to facilitate the viable mechanism to integrate. The thesis has chosen four direct routes and one loop as shown in figure 5.20. Fixed Route Loop L0 – SAVs will use the blue colored loop as scheduled mobility. The loop makes 2.27km long and takes around 5 +/- minutes with a maximum speed of 30 km/h. The street has an average width of 8 meters. Route (A, B, C, D)1 – S0 – (A, B, C,)2 – the route is designated for demand-oriented mobility with possible extensions. The whole route makes 3 km. In the figure, the routes are divided into two parts making each 1.5km long. SAVs driving at a 30 km/h will complete the trip (with return trip) to in either direction on 6 +/- minutes. The width of the roads has an average of 8 meters with some exception area which has more space.

5.5 SUMMARY OF ANALYSIS OF THE IMPACT OF SAVs IN STAVANGER CITY CENTER

Investigating how SAVs could impact the urban land use and mobility in Stavanger city center demands to characterize the urban structure of the city center and what the city development plans are. Stavanger city is developed in a polycentric model based on car transport. (Næss, Peters, Stefansdottir, & Strand, 2018) The city has a segregated land use pattern with specific locations dedicated to specific functions. However, the city is now working to change the car dependency through strict measures to reduce the VKT and giving priority to sustainable modes of transport. The city has introduced new bus roads to increase the accessibility and reduce the waiting time in traffic for public transport.

The thesis investigated the impact of SAVs on the city center in two major themes which are the impact on the parking areas and impact on the transport infrastructures. Both themes lead to freeing areas designated to cars and increase mobility. The outcome of both changes enhances the attractiveness of the city center. The changes anticipated with the introduction of SAVs is done presuming that the requirements and barriers to the development of AVs both technically and legally are resolved.

Stavanger city center has around 8500 registered parking places. Around 4700 of them are available as a public parking area with the rest registered as a private parking area. To estimate the amount of area designated for all 8500 parking areas is difficult as the designated for parking on the roadside and parking area or parking building is different. However, the thesis has identified 3,390 parking areas which only makes 40% of the total registered parking areas. The selected parking areas make a total area of 65,650 m2. The calculation did not include the area needed for the runway, the ramp or the pedestrian walking areas. The selected area, however, corresponds to approximately seven football fields.

To further highlight the impact of SAVs on the parking area in the city, the thesis analyzed Stavanger station, Holmen, and Vågen. Stavanger station has an area of around 30 000 m2, and the parking area covers around 10,000 m2. The parking area covers one-third of the total area dedicated to the station. On the contrary, the local buses have their local stops all over the lake Breiavatnet, which makes transit difficult for the public transport users. The station at the moment does not have an organized central station.

Holmen has the largest area which is dedicated to parking than the other two. The car parking covers an area around 20,000 m2. The area has low utilization rate compared to the importance of the area and having the waterfront at its disposal. Similarly, Vågen is a strategic harbor at the heart of the city center. The area is also affected by car parking and car traffic. The area has an area of 13,000 m2 designated to car parking. The streets bounding the harbor have different functions, which creates in balance in the flow of people. Both streets, however, function to their potential when there are festivals and occasions like May the 17th.

SAVs also have the potential to change the transport infrastructure. They bestow a new opportunity for the public transport to improve the accessibility and mobility in the city center. People do not perceive that the current public transport suits their everyday activities. The county uses society's tax money to subsidize the buses to keep them on schedule. The integration of SAVs has a potential to change peoples experience and increase the efficiency of the public transport. Stavanger city center is not accessible with the public transport which also forces people to use their cars. However, the integration of SAVs could improve the accessibility of the city center with public transport. SAVs could also increase public transport services to the boroughs surrounding the city center such as Eiganes, Storhoug, Våland, and Byhaugen.

SAVs could further reduce the average daily traffic in the city center. The streets surrounding Stavanger station, Holmen, and Vågen are highly trafficked which affects the attractiveness of the city center and the experience of the visitors and the people that live there. Reducing ADT in the city center is not a prerogative impact of the SAVs. However, they could provide a means for easy accessibility in the city center which could compensate any strict measures taken in the city.

The integration of SAVs would also require the restructuring of the transport infrastructure. In order SAVs aid in achieving sustainable mobility, the public transport needs a new model that reduces the time of travel. The public transport needs to create a direct transit between the boroughs which also could suit the polycentric structure of Stavanger municipality.

The integration of SAVs is more applicable in the city center as the streets almost have a speed limit which is suitable for the implementation of SAVs. However, integrating SAVs without any reforms to the car parking or access to the city with private vehicles could be more challenging and could create situations which are hazardous to the safety of trafficants.

The presumed impacts SAVs could have in the city center, all lead in changing the attractiveness of the city center. The changes that could come in the city center, whether it is reducing the road width, removing the parking area, restricting personal vehicles or improving accessibility, they all improve the people's experience in the city center and the municipality.

5.5.1. INTEGRATING SAVs IN STAVANGER CITY CENTER

The thesis has investigated the potential scenarios to implement SAVs in Stavanger city center, which could aid to achieve sustainable mobility. The thesis looked two alternatives that one focuses on computing with the traditional public transport and the second one as integrated part of the public transport. Although both alternatives support the theme of the thesis creating a new model that could make the old one obsolete, the thesis has decided to look SAVs as an integrated part of the public transport. The alternative has two scenarios where SAVs could function as part of the public transport. SAVs could function as scheduled mobility providers or demand generated mobility providers. Both alternatives have their strength and weakness. People could perceive both scenarios as restrictive mobility and nonrestrictive mobility. Those people that can order and plan their trips could think scheduled mobility is restrictive mobility, while those that do not have the means and ability to order beforehand and relay on the scheduled timetable could think demand generated mobility is restrictive. The perspective towards the scenarios changes with what criteria one uses.

Therefore the thesis had chosen to use both scenarios and create a new third scenario "Mixed Mobility." The mixed mobility incorporates both scheduled mobility and demand generated mobility. Both alternatives are restricted to location. Scheduled mobility is to function in areas where there is a need to limit the number of vehicles passing through a particular location and dense areas. Demand-oriented mobility is to function in residential areas and in areas where there is less need for scheduled mobility. Hence, the thesis has chosen a base route with a free-floating system of routing to facilitate the mixed mobility. The thesis choose four direct routes and one loop. The scheduled mobility gives service in the loop while the demand-oriented mobility will provide service in the other routes. In choosing the routes, the thesis considered the width of the streets and the activity on the ground floor. The loop is 2,27km long, and the other routes have a base distance of 1.5km in each direction from the central station. The time needed to complete the trip takes around 5 to 6 minutes depending on the speed of the vehicle.

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CHAPTER SIX

CONCLUSION

6. CHAPTER SIX - CONCLUSION

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The master's thesis aim was to unravel new possibilities and opportunities to transform mobility. It has also focused on the potential of transforming the city with new ideas and developing technologies. The thesis had a quote taken from the book After the Car, which emphasizes the challenges ahead in transforming the mobility to sustainable mobility. And the quote :

"You never change anything by fighting the existing reality. To change something, build a new model that makes the existing model obsolete."

(Dennis & Urry, 2009)

The overall goals of changing the mobility to sustainable mobility are to provide the ability and accessibility to move freely without affecting essential human or ecological needs of the future generations. (Williams, 2007) The concept of achieving sustainable mobility relates to sustaining economic, social and environmental pillars of the society. Mr. Gillespie described that planning practices have tried to solve future problems applying experience and knowledge about the past instead managing the future. (Gillespie, 2016) However, the technological development has come as a means to solve the societal challenges.

The public transport services provided at the moment are so inadequate that people are more dependent on personal vehicles for their everyday activities. To change the car dependency and enhance the public transport efficiency requires a new model that could function as public transport but provides mobility with the same efficiency as the personal vehicles. As a result, the development of SAVs provides an opportunity to obsolete the car dependency.

The research questions investigated on two questions,

"How could SAVs be integrated to help achieve sustainable mobility?"

And

"How could SAVs impact the urban land use and mobility in Stavanger city center?"

The research questions encompass essential themes providing a new mobility paradigm and the impact of the changes that could come. Achieving sustainable mobility is a prime motive of investigating how to integrate SAVs in Stavanger city center. The development of AVs is a market-driven with a broad and distinctive vision. The visions have different perspectives.

The car manufacturers and service providers see the development of AVs as getting a new customer base. The government or local authorities look the development as a potential to increase the efficiency of the public transport, reduce the need to build new infrastructures, and the amount of subsidizing paid for the service providers to keep the buses in the scheduled timetable. Mr. Solvik-Olsen highlighted that the intentions for the ministry of transport are to provide people better mobility not own autonomous vehicles. (Solvik-Olsen, 2018)

6.1. HOW COULD SAVs BE INTEGRATED TO HELP ACHIEVE SUSTAINABLE MOBILITY?

"Everything … Affects Everything"

Jay Asher

The thesis analyzed AVs and SAVs through interviews with people related to the development of the technology, people related to making regulations and standardizing, and people related to the implementing of the vehicles. The thesis covered topics related to the requirements of the technological development, standardizing and legal developments. The thesis found out that technology is developing very fast, but to integrate the AVs or SAVs would require that the technology be reliable at all times and function in all conditions. The development of AVs in Norway is focused not only on the vehicles to be autonomous but at the vehicles are connected to each other. At the moment, the vehicles have flaws in their development of the communication technology, protecting personal privacy and cyber-security. The vehicles could communicate with each other if they are from the same producer, but could not communicate among different vehicle models. Moreover, the vehicle's technological development and their status are kept secret by the OEMs.

To integrate the vehicles demand necessary standards that regulate the vehicles and laws that prevent misunderstands Preparing standards usually proceed after the product that needs standardizing has provided service to the public. It is the market that dictates what to standardize. As the technological development of SAVs or AVs is not available to the public, standardizing has become extra challenging. Almost all standardization works of AVs is being conducted internationally, and Norway does not have any participation on the current standardization of SAVs. Mr. Husøy further highlighted that within Standard Norway, there is a deficiency of essential knowledge and experience to prepare standards, which also could delay the integration of SAVs or AVs. The thesis also found out that the telecom and the OEMs are lobbying to impose their standards to be the policy and regulation rather the standards prepared by ISO. At the moment, no standard is put as a mandate.

Integrating SUVs also have other barriers which relate to the functionality of the vehicles and the requirements of the development of the vehicles. The thesis has found out that there is lack of information, the challenges of the society's ability to easily maneuver or drive the vehicles, and moral and ethical questions.

The thesis has found out that to integrate SAVs would require that the technical development, standardizing, and policies need to be in place. Jay Asher has said that everything affects everything. One action affects the other. The technological development of the vehicles is still developing, and people working on the development think that the technology is capable of being implemented. The lack of standard and regulation would delay the integration of the vehicles, but the everchanging technology is also making standardizing and preparing regulations very difficult.

Achieving sustainable mobility and integrating SAVs would demand, as Mr. Scharfe explained, the people that regulate the law, people that build the technology and people that implement the technology to work together. To achieve sustainable mobility, it does not solely depend on the vehicles, but it depends on how the society want to live. How AVs function in the society is also dependent on how the society wants to move. Integrating SAVs to aid Sustainable mobility requires a significant change in land use and mobility paradigm.

6.2. HOW COULD SAVs IMPACT THE URBAN LAND USE AND MOBILITY IN STAVANGER CITY CENTER?

“ We Do Not Know What We Do Not Know.”

(Zielenski, 2018)

SAVs has a potential to free up land used for car parking and change the transport infrastructure in cities. There is a presumed change that the vehicles could impose in the cities, but no one knows how it will change the cities and what the change will be. SAVs are only a tool that could facilitate mobility. Facilitating sustainable mobility, however, depends on how the society wants to use the vehicles.

The thesis analyzed the urban structure of the city center, and city regulation plans to investigate how SAVs could impact the urban land use and mobility in Stavanger city center. The municipality has a polycentric model-based development. The city has a segregated land use pattern with specific locations dedicated to specific functions (Næss, Peters, Stefansdottir, & Strand, 2018).

The thesis investigated the impact of SAVs on the city center in two major themes which are the impact on the parking areas and impact on the transport infrastructures. Both themes lead to freeing areas designated to cars and increase mobility. The outcome of both changes enhances the attractiveness of the city center. The changes anticipated with the introduction of SAVs is done presuming that the requirements and barriers to the development of AVs both technically and legally are resolved.

The analysis identified that the city center has 8500 registered parking places. There are 4700 public parking areas and 3800 private parking areas. The thesis tried to identify the total potential area that could be freed in the city. To estimate the amount of area designated for all 8500 parking areas was difficult. However, the thesis has identified 3,390 parking areas which only makes 40% of the total registered parking areas. The selected parking areas make a total area of 65,650 m2. Freeing the identified area corresponds to approximately seven football fields. The thesis also investigated in detail locations within the city such as Stavanger Station, Holmen, and Vågen. It found out that parking areas dominate the locations and the areas have a massive potential in the transforming the city.

SAVs bestow a new opportunity for the public transport to improve the accessibility and mobility in the city center. People do not perceive that the current public transport suits their everyday activities. Stavanger city center is not accessible with the public transport which also forces people to use their cars. The thesis also identified that the integration of SAVs could reduce average daily travel in the city center and increase accessibility to the area with public transport. SAVs could also increase public transport services to the boroughs surrounding the city center such as Eiganes, Storhoug, Våland, and Byhaugen.

Further, the thesis investigated the potential scenarios to implement SAVs in Stavanger city center, which could aid to achieve sustainable mobility. The thesis looked two alternatives that could aid the integration of SAVs. One focuses on computing with the traditional public transport and the second one as integrated part of the public transport. Although both alternatives support the theme of the thesis creating a new model that could make the old one obsolete, the thesis has decided to look SAVs as an integrated part of the public transport to achieve sustainable mobility.

The alternative has two scenarios where SAVs could function as part of the public transport. SAVs could function as scheduled mobility providers or demand generated mobility providers. The thesis analyzed both scenarios to facilitate the integration of SAVs. The thesis chose to use a combination of both scenarios “MIXED MOBILITY.” The thesis recommended routes that could aid achieve sustainable mobility. It highlighted that the use of both scenarios to accommodate the routes proposed would need that the vehicles also function in a system where the scheduled vehicles operate within a base and the demand generated vehicles could operate in the routes with possible extensions. The thesis recommended the distance of the routes in the base area to not exceed time travel of 5 to 6 minutes for the whole trip.

The presumed impacts SAVs could have in the city center, all lead in changing the attractiveness of the city center. The changes that could come in the city center, whether it is reducing the road width, removing the parking area, restricting personal vehicles or improving accessibility, they all improve the people’s experience in the city center and the municipality. However, changing the attractiveness and livability of the city center does not solely rest on the shoulders of SAVs. They provide a means for the society to change its norms and mobility cultures, but the changes depend on how the society wants to move or live.

6.3. RECOMMENDATION FOR FUTURE STUDIES

The integration of SAVs in cities and their impact on land use and mobility also have other new challenges. The expectation with SAVs or AVs is that they are going to bring change in the cities. As the thesis concluded no one knows what the change is. It has tried to analyze the potential of the vehicles in transforming the transport infrastructure and free land used for car parking. However, there needs that we also are aware of the unintended change that could come.

SAVs could also impact the society in different aspects. Moreover, the thesis has identified the following research needs:

- It is not clear how the integration of SAVs could impact the public health. There needs a study on what consequence does the vehicles impose in the public health.
- The integration of SAVs would demand a new mobility paradigm. There needs a study on how the transport infrastructure could be restructured.
- There is no explicit estimation of the cost of transforming the transport infrastructure with the integration of SAVs. There needs to be done a cost and benefit analysis of the implementation of the vehicles.

Many other SAVs related fields need a broad investigation. The thesis investigated some of the legal, technical and standardizing challenges in the development of the vehicles. Each theme covers a broad study field.

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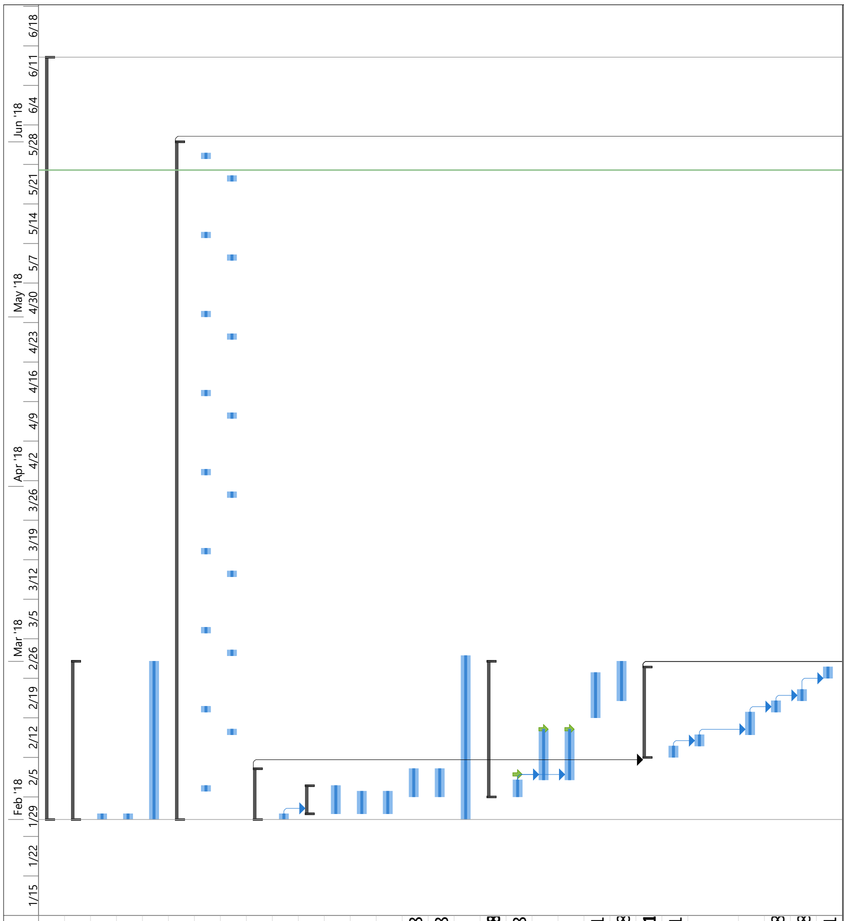
LIST OF FIGURES AND TABLES

PROGRESS PLAN

ID	Task Name	Duration	Start
1	**Master Thesis Project**	**97 days?**	**Thu 2/1/18**
2	**Preparation for the Project**	**20 days?**	**Thu 2/1/18**
3	Joint supervison meeting	1 day	Thu 2/1/18
4	Signing of contracts	1 day?	Thu 2/1/18
5	Preparing of time schedule	20 days?	Thu 2/1/18
6	**Urban planning: How AV transform our cities?**	**86 days?**	**Thu 2/1/18**
7	**Supervision with UiS**	**81 days**	**Tue 2/6/18**
17	**Supervision with SVV**	**71 days**	**Fri 2/16/18**
26	**Introduction**	**7 days?**	**Thu 2/1/18**
27	Introduction	1 day?	Thu 2/1/18
28	**Background History**	**3 days**	**Fri 2/2/18**
29	What are AV?	3 days	Fri 2/2/18
30	Stavanger Municipality	2 days	Fri 2/2/18
31	Kongsberg Municipality	2 days	Fri 2/2/18
32	Theme	5 days	Mon 2/5/18
33	Research question	5 days	Mon 2/5/18
34	Choosing and contacting people for interview	21 days	Thu 2/1/18
35	**Philosophy of science and Methodology**	**22.25 days**	**Mon 2/5/18**
36	American pragmatism	3.5 days	Mon 2/5/18
37	Research strategy	7 days	Thu 2/8/18
38	Data collection and Analysis	7 days	Thu 2/8/18
39	Strength and weakness	6 days	Mon 2/19/1
40	Validity	5 days	Thu 2/22/18
41	**Theory**	**12 days**	**Mon 2/12/1**
42	Sustainable Mobility	2 days	Mon 2/12/1
43	Autonomous vehicles impact in Urban Land Use and transport infrastructure	2 days	Wed 2/14/18
44	Managing Transport Infrastructures	2 days	Fri 2/16/18
45	Land Use	2 days	Tue 2/20/18
46	Density	2 days	Thu 2/22/18
47	Policies and planning	2 days	Mon 2/26/1

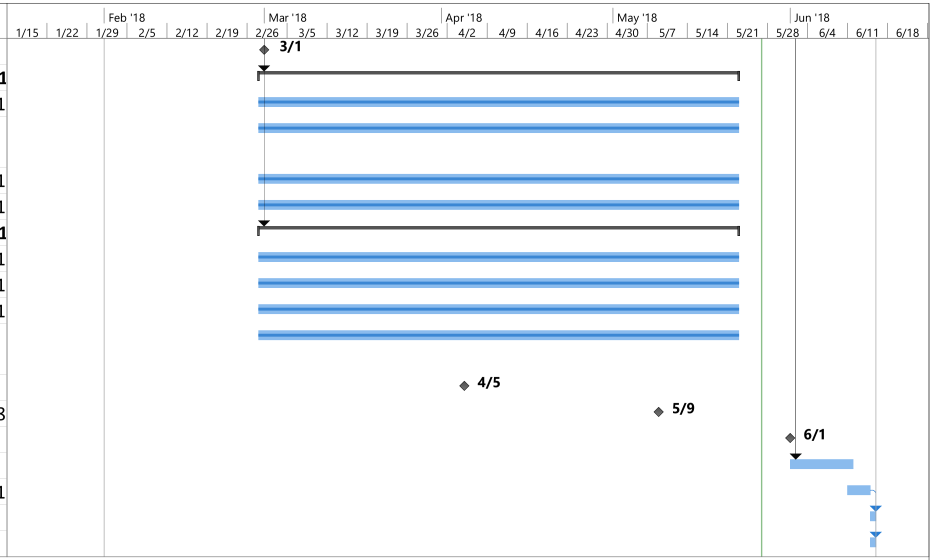


Project: Time schedule
Date: Sun 5/27/18

Task, Split, Milestone, Summary, Project Summary, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, External Tasks, External Milestone, Deadline, Progress, Manual Progress

Page 1

ID	Task Mode	Task Name	Duration	Start
48		First supervisor meeting	0 days	Thu 3/1/18
49		**Possible Approach to Integrate SAVs**	**60 days?**	**Wed 2/28/1**
50		The Vision and Timeframe of AVs	60 days?	Wed 2/28/1
51		The Requirements For the Integrate Autonomous Vehicles	60 days?	Wed 2/28/18
52		Barriers to Integrate Autonomous Vehicles	60 days?	Wed 2/28/1
53		Interventions and strategies to integrate SAV	60 days?	Wed 2/28/1
54		**Stavanger City Center**	**60 days?**	**Wed 2/28/1**
55		Urban Structure and Topography	60 days?	Wed 2/28/1
56		How We Want to Live	60 days?	Wed 2/28/1
57		Potential Impact of SAVs in Stavanger City Ce	60 days?	Wed 2/28/1
58		Implementing Shared Autonomous Vehicles in Stavanger City Center	60 days?	Wed 2/28/18
59		Second supervisor meeting	0 days	Thu 4/5/18
60		Third supervisor meeting	0 days	Wed 5/9/18
61		Last milestone for proofreading	0 days	Fri 6/1/18
62		proof reading	7 days	Fri 6/1/18
63		print the project	4 days	Mon 6/11/1
64		Hand in project	1 day?	Fri 6/15/18
65		Presentaion	1 day?	Fri 6/15/18



Project: Time schedule
Date: Sun 5/27/18

Task | Project Summary | Manual Task | Start-only | Deadline
Split | Inactive Task | Duration-only | Finish-only | Progress
Milestone | Inactive Milestone | Manual Summary Rollup | External Tasks | Manual Progress
Summary | Inactive Summary | Manual Summary | External Milestone

Page 2

A.1 PARKING AREAS IN STAVANGER CITY CENTER

No.	Parking Name	Type of Parking	Capacity	Area (m2)
1	P - St. Olav	Parking House	480	9 600 m2
2	P - Jernbanen	Parking House	500	10 000 m2
3	P - Radisson Blue Atlantic Hotel	Parking House	23	460 m2
4	P - Kyrre	Parking House	310	6 200 m2
5	P -Posten P-Hus	Parking House	150	3 000 m2
6	P - Straen Senteret	Parking House	150	3 000 m2
7	P- Domkirkeplassen	Parking House	50	1 000 m2
8	P -Arkaden	Parking House	75	1 500 m2
9	P - Arketten	Parking House	200	4 000 m2
10	P - Valberghallen	Parking House	170	3 400 m2
11	P - Jorenholmen	Parking House	500	10 000 m2
TOTAL			**2 608**	**52 160 m2**

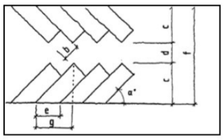
Table A.1. Parking in a Building

No.	Parking Name	Type of Parking	Capacity	Area (m2)
1	Nytorget	Street Parking	15	150 m2
2	Vaisenhusegata 5-7	Street Parking	5	50 m2
3	Vaisenhusegata 24-30	Street Parking	7	70 m2
4	Nedre Strandgate 33-43	Street Parking	17	170 m2
5	Nedre Strandgate	Street Parking	12	120 m2
6	Øvre Holmegate	Street Parking	18	180 m2
7	Kirkegata	Street Parking	5	50 m2
8	Valberggata	Street Parking	10	100 m2
9	Nedre Holmegata 30	Street Parking	10	100 m2
10	Skansegata	Street Parking	4	40 m2
11	Olav Kyrres Gate	Street Parking	25	250 m2
12	Knud Holms gate	Street Parking	10	100 m2
13	Løkkeveien v/nr 15	Street Parking	4	40 m2
14	Sankt Olavs Gate	Street Parking	9	90 m2
15	Sankt Svithuns gate	Street Parking	5	50 m2
16	Stiftelsesgata	Street Parking	16	160 m2
17	Vaisenhusgata	Street Parking	21	210 m2
18	Bergensgata 30	Street Parking	7	70 m2
19	Breibakken 11	Street Parking	6	60 m2
20	Hetlandsgata	Street Parking	9	90 m2
TOTAL			**215**	**2 150 m2**

Table A.2. Parking on the side of the road

No.	Parking Name	Type of Parking	Capacity	Area (m2)
1	P - St. Olavs Gate	Surface Parking	12	240 m2
2	P - Cort Adelers Gate	Surface Parking	12	240 m2
3	P - Olav Kyrres Gate	Surface Parking	145	2 900 m2
4	P - Posten	Surface Parking	28	560 m2
5	P - Strandkaien Sør	Surface Parking	21	420 m2
6	P - Strandkaien Nord	Surface Parking	45	900 m2
7	P - Skansekaien	Surface Parking	37	740 m2
8	P - Skansegata	Surface Parking	12	240 m2
9	P - Skagenkaien	Surface Parking	44	880 m2
10	P - Ryfylkekaien	Surface Parking	36	720 m2
11	P - Holmeallmenningen	Surface Parking	92	1 840 m2
12	P - Kjerringholmen Ved Oljemuseu	Surface Parking	31	620 m2
13	P - Verksgata	Surface Parking	27	540 m2
14	P - Verven	Surface Parking	12	240 m2
15	P - Lars Hertervigs Gate	Surface Parking	13	260 m2
TOTAL			**567**	**11 340m2**

Table A.3. Parking on the surface

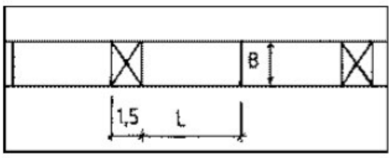


Figur 20.6

Parkeringsanlegg for personbil. Ved hj�rner b�r b v�re 0,5 m bredere. Hvis overheng tillates kan c v�re noe mindre.

α°	b	c	d	e	f	g	Areal pr. bil: m² brutto for 10 pl.	Areal pr. plass n�r 100 plasser anlegges
45	2,30	5,2	2,8	3,2	13,2	5,2	27,9	21,9
60	2,30	5,5	4,0	2,7	15,0	3,2	24,7	20,4
90	2,30	5,0	7,0	2,3	17,0	2,3	19,5	19,5
45	2,40	5,2	2,8	3,4	13,2	5,2	29,4	23,2
60	2,40	5,5	3,8	2,8	14,0	3,2	25,3	21,1
90	2,40	5,0	6,5	2,4	16,5	2,4	19,8	19,8
45	2,50	5,3	2,8	3,5	13,4	5,3	30,6	24,3
60	2,50	5,6	3,5	2,9	14,7	3,2	25,8	21,6
90	2,50	5,0	6,0	2,5	16,0	2,5	20,0	20,0

Figure A.1. Parking on the surface (Staten Vegvesen, n/a)



Type kj�ret�y	B (m)	L (m)
P	2	5
LL	3	8
L	3	13

Figure A.2. Parking on the side of the road (Staten Vegvesen, n/a)

A.2 INTERVIEW GUIDE

A.2.1 QUESTIONS FOR LOCAL AUTHORITIES

1. What are your background and your role?
2. What are the most significant concerns and issues with the way that automated vehicle technology has developed and been tested? What are the most significant concerns about automated vehicles on the roadway? What benefits do you anticipate from automated vehicles?
3. Fully automated vehicles are expected to be on the market as soon as 3-5 years from now. Do you feel the organization needs to prepare or take any actions in advance?
    a. What actions, if any, has the organization/state taken in preparation?
    b. What was the intent of the action(s), legislation, or regulation?
    c. How were the actions determined? Did you involve the automated vehicle industry or other technically proficient groups? In what capacity?
    d. Have you received any feedback (industry or otherwise) after taking the actions, passing legislation, or implementing regulations?
4. What do you think is the possible transitional approach to autonomous vehicles in developing sustainable mobility within the region that support the NTP?
    a. What do you think is the early implementation mechanism for autonomous vehicles?
    b. Do you think the transport infrastructure could support such vehicles?
    c. How would that influence public transport plans for the region?
    d. Do you think making autonomous vehicles operate in dedicated lanes or managed lanes at the start phase is the beneficiary to implement autonomous vehicles?
    e. The region administration spends much money in subsidizing the public transport to have a planned timetable for the public transport.
        i. How would the county's administration benefit from implementing shared autonomous vehicles in public transport sector?
        ii. How do you think the cost of using public transport be influenced? Do you think the prices would increase or decrease? Does the regional administration have a role in monitoring the prices demanded from public transport providers?
5. The transport sector is employment provider for many people, People that are working on public transport, taxi, driving schools, …etc.
    a. How do you see the unemployment problems that could be created with the implementation of shared-autonomous vehicles?
6. Do you think we have to readjust our planning practices, revisit our strategies and readjust infrastructures to incorporate Shared-Autonomous vehicles?

7. What do you think the benefits of using shared autonomous vehicles as First/Last Mile solution INTEGRATED to the traditional public transport system would have to the region?
    a. Do you think Shared-Autonomous Vehicles as first/last mile solution can function in the current infrastructure in the region?
    b. Would the regional administration support such development as an early transition to autonomous vehicles?
        i. Do you think the existing strategies could work in such measures?
    c. How do you the urban development agreement with uses toll financing system would benefit providing such alternatives?
8. Do you think there is a possibility of getting some data for the department? Such as:
    - Distribution of workplaces
    - Travel pattern and travel habits
    - Demographical data

Thanks for your time!
If there is anything you want to add, feel free to say it.

A.2.2 QUESTIONS FOR SERVICE PROVIDERS

1. What are your background and your role?
2. What is the vision and goals of those autonomous vehicles?
3. Over what time frame do you see Shared Automated Vehicles developing capabilities consistent with automation levels five (full automation)?
    a. When will the enabling technologies like lidar, radar, or computer-based image recognition be sufficiently developed to enable these levels of functionality?
4. Now, all car producers are developing their technology. However, how do you see autonomous vehicles developing? Will they use standard technology, or will it be a combination of technologies?
    a. Are there any standards that have been required from the Norwegian road authority or Norway standards?
5. Studies show that planners have not incorporated autonomous vehicles because of the insecurities about when they will be available and not knowing what is needed for the autonomous vehicle to function safely. Therefore,
    a. Do you think the roadway infrastructure, digital infrastructure, maps, or other associated data will need to change to accommodate autonomous vehicles? In what way(s)?
    b. Even if not required, are there any changes to roadway infrastructure or DOT (Department of Transportation) operations that would facilitate automated vehicle development?
    c. How could infrastructure help?
6. At the moment, all autonomous vehicle producers are working with different V2V and V2I communication technologies. As a result, vehicles from the same manufacturer communicate to each other, while they cannot communicate to other vehicles from a different manufacturer.
    a. What should be done to create a safe environment for the implementation of the autonomous vehicles and safety of the people?
    b. How could existing vehicles communicate with the autonomous vehicles?
    c. Do you think people are capable of reading the intentions of autonomous vehicles actions and react to it in good time to avoid accidents?
    d. Can vehicle platooning be accomplished with the existing vehicles on the road?
7. What do you think is the early implementation mechanism for autonomous vehicles?
    a. Do you think making autonomous vehicles operate in dedicated lanes or managed lanes at the start phase is the beneficiary to implement autonomous vehicles?
8. How do you see the state legislation on autonomous vehicles in providing a foundation to test or implement autonomous vehicles?
    a. Has any state's legislation had an especially profound effect (positive, negative, or neutral)?
    b. What aspects of legislation or regulation have the most pronounced effect?

9. What role do you see for the state, or local governments have in the automated vehicle development and implementation process?
10. How would you characterize the societal and economic benefits of autonomous vehicles or shuttle buses?
    a. What do you see as the benefits of Autonomous vehicles in the case of this pilot project?
    b. Kolumbus now is employment provider for many bus drivers.
        i. How do you see the future of those workers?
        ii. What kind of job opportunities could autonomous vehicle provide within Kolumbus?
11. How could Kolumbus autonomous vehicles provide adequate access to the people with affordable prices?
    a. Would they be used in a dedicated route with specific time table or are they thought to function as in demand transport?
12. What should be done with regard to safety for the users and pedestrians "social dilemma"?
    a. Do you think autonomous vehicle should choose the fatalities in case of an avoidable accidents?
13. Cybersecurity and privacy issues are an increasingly important issue in the public consciousness.
    a. How could issues of privacy and data ownership from the use of autonomous vehicles be managed? How could the issues regarding privacy and surveillances be managed?
14. What sort of liability concern do you have with regard to the shuttle Autonomous buses that could hinder the implementation of the vehicles?
15. What do you think on how the transition planning with DOT, regional and municipal sectors should include Automated vehicles in their planning?
    a. How and what should be done in order planner to include automated vehicles in their program?
16. How do you see Stavanger municipality with autonomous vehicles as a mobility provider in the future?
    a. What kind of challenges do you anticipate?

Thanks for your time!
If there is anything you want to add, feel free to say it.

A.2.3 QUESTIONS FOR TECHNOLOGY DEVELOPERS

1. What are your background and your role?
2. What is the vision and goals of an autonomous vehicle?
3. Over what time frame do you see Shared Automated Vehicles developing capabilities consistent with automation levels five (full automation)?
    a. When will the enabling technologies like lidar, radar, or computer-based image recognition be sufficiently developed to enable these levels of functionality?
    b. Do you think that technological advancements on Autonomous vehicles could be developed enough to manage unexpected situations?
4. Now, all car producers are developing their technology. However, how do you see autonomous vehicles developing? Will they use standard technology, or will it be a combination of technologies?
5. Studies show that planners have not incorporated autonomous vehicles because of the insecurities about when they will be available and not knowing what is needed for the autonomous vehicle to function safely. Therefore,
    a. Do you think the roadway infrastructure, digital infrastructure, maps, or other associated data will need to change to accommodate autonomous vehicles? In what way(s)?
    b. Even if not required, are there any changes to roadway infrastructure or DOT (Department of Transportation) operations that would facilitate automated vehicle development?
    c. How could infrastructure help?
6. Autonomous vehicles are equipped with a vehicle to vehicle and vehicle to infrastructure communication mechanisms. However, for autonomous vehicles to operate in all parts of our cities, there is a need the existing cars and infrastructures communicate with the autonomous vehicles. So
    a. At the moment, all autonomous vehicle producers are working with different V2V and V2I communication technologies. And as a result, vehicles from the same manufacturer communicate to each other, while they can not communicate to other vehicles from a different manufacturer.
        i. What should be done to create a safe environment for the implementation of the autonomous vehicles and safety of the people?
    b. How could existing vehicles communicate with the autonomous vehicles?
    c. Do you think people are capable of reading the intentions of autonomous vehicles actions and react to it in good time to avoid accidents?
    d. Can vehicle platooning be accomplished with the existing vehicles on the road?
7. The predictions in this early stage of autonomous vehicles are that they tend to reduce congestion and increase safety.
    a. What do you think is the early implementation mechanism for autonomous vehicles?
    b. Do you think making autonomous vehicles operate in dedicated lanes or managed lanes at the start phase is the beneficiary to implement autonomous vehicles?

8. How do you see the state legislation on autonomous vehicles in providing a foundation to test or implement autonomous vehicles?
    a. Has any state's legislation had an especially profound effect (positive, negative, or neutral)?
    b. What aspects of legislation or regulation have the most pronounced effect?
9. What role do you see for the state or local governments have in the automated vehicle development and implementation process?
10. How would you characterize the societal and economic benefits of autonomous vehicles?
11. What should be done about safety for the users and pedestrians "social dilemma"?
    a. Do you think the autonomous vehicle should choose the fatalities in case of an avoidable accident?
12. Cybersecurity and privacy issues are an increasingly important issue in the public consciousness.
    a. Do you see any role for the federal, state and local government and how could they aid in providing a safe zone for autonomous vehicles?
    b. Do you see cybersecurity as a risk to autonomous vehicles?
    c. How could issues of privacy and data ownership from the use of autonomous vehicles be managed?
        i. How do you think will affect users when the surveillance and privacy are to be managed separately with OEMs or as a central system within the government?
13. What sort of liability concern do you have about Autonomous vehicles that could hinder the implementation of the vehicles?
    a. Does it delay or prevent implementation or development?
    b. How can legislation or regulation mitigate your liability concerns?
    c. Is this an issue for federal or state governments to address?
14. What do you think about how the transition planning with DOT, regional and municipal sectors should include Automated vehicles in their plan?
    a. How and what should be done in order planner to include autonomous vehicles in their program?

Thanks for your time!
If there is anything you want to add, feel free to say it.

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