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Exploring policy influence on diffusion in an autonomous vehicle context

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Contents

ABSTRACT

In this master thesis we will examine how the diffusion of autonomous vehicle (AV) technology can be influenced by policy makers. The thesis uses the Rogaland region as its empirical case, and constructs scenarios based on the future developments of key factors related to technology diffusion. The research question follows:

How can policy selection help influence an increased rate of diffusion of AV technology into public transit (PT) in the Rogaland region?

We explore fundamental theories related to the diffusion and adoption of technologies. Primarily we examine the diffusion of innovations and the technology acceptance model. We bridge the theory of diffusion to our empirical study of autonomous vehicle technologies in Rogaland and identify perceived risk and perceived usefulness as the main drivers of diffusion.

We identify four main scenarios with different degree of diffusion, where the *transformation* scenario is the one who offers the highest rate of diffusion. This scenario requires continuation of the current policies supporting AV adoption in Rogaland. It also requires optimizing communication with the public regarding the objective risk of AV to reduce perceived risk.

ACKNOWLEDGMENTS

This thesis would not be possible without substantial support from our advisor and our families. We thank them for their unending patience and understanding. Our work owes a special thanks to Kolumbus, who were kind enough to provide us with data. Thank you to Derk Loorbach & Roel van Raak for allowing us to cite their work on transition management. The master thesis has been a challenging and rewarding endeavour. Any mistake found in this work is solely our own.

LIST OF ABBREVIATIONS

Saker

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1 INTRODUCTION

The idea of autonomous mobility has been a vision of the future for a long time. In the past decade, this vision seems to be coming closer to becoming reality. As with all technology there are numerous obstacles that needs to be overcome, but it may appear that we now are on the verge of overcoming the most significant technical ones. Technical obstacles, however, is only one piece of the puzzle, as humans are fundamentally sceptical of change. This fundamental resistance to change presents a societal challenge. Thus, introducing new technologies is not an instantaneous event. Integration with older technologies takes time even with superior new technology. When it comes to technology with the potential to change complex systems, it often becomes the subject of various policies either advancing or hindering its adoption as society decides how to react. Determining how to optimize diffusion is a daunting task that requires examination of what drives diffusion and then to determine how different polices will impact this rate of diffusion. The potential of the technology also means that there are many ways it can be developed into the future. In a world eternally scrambling for scarce resources, finding ways to free up human capital is worth pursuing.

Trying to influence diffusion of technology requires a broad and strategic look. Combining the more general theories with a specific technology and geographical location can give a less abstract space to work with. Most of the testing on autonomous vehicle (AV) technology is being done in densely populated areas. By looking through a more modest region, it might be possible to create scenarios on how this region can influence its rate of adoption. We have chosen the Rogaland region, as it offers an alternative to other studies and it already has some active policies promoting the adoption of AV technology. The region is also relatively wealthy, with the finances to integrate costly systems if desirable, and is generally considered early adopters of new technologies. The policies considered will focus on those possible to influence by the regional government. In this case the regional government also holds a monopoly on public transport (PT), which broadens the scope of control and the possibilities of introducing policies. The problem statement thus becomes:

> *How can policy selection help influence an increased rate of diffusion of AV technology into public transit (PT) in the Rogaland region?*

2 LITERATURE REVIEW

Policy makers are often faced with new technologies promising a revolution in the way we connect with the world. To advance promising technologies, it becomes necessary to examine which mechanisms drive technological diffusion in general. The path from a technical breakthrough every day usage differs depending on whether the technology is an improvement on an existing technology or something more radically new. Innovations often come with high risks in the form of capital costs or uncertainty around the viability of its adoption. We will examine which factors affect the adoption of new innovations and seek to identify fundamental drivers. Further, we will discuss potential solutions policy makers can use influence these drivers.

Our main sources have been Orio, Google Scholar, and the University of Stavanger’s library.

2.1 TECHNOLOGICAL DIFFUSION

Technological diffusion seeks to explain how new technologies spread among households and individual firms in a market. Examining theories on this process, reveals the underlying mechanisms. Going into the mechanisms of diffusion will allow identification of key drivers. Technological diffusion happens over time and there are several models developed for explaining the rate of adoption.

2.1.1 Diffusion of innovations

The theory of diffusion was popularized by Everett Rogers in 1962. The diffusion of innovation can be defined as follows:

Diffusion of innovations refers to the spread of abstract ideas and concepts, technical information, and actual practices within a social system, where the spread denotes flow or *movement from a source to an adopter, typically via communication and influence* (Wejnert, 2002, p. 297).

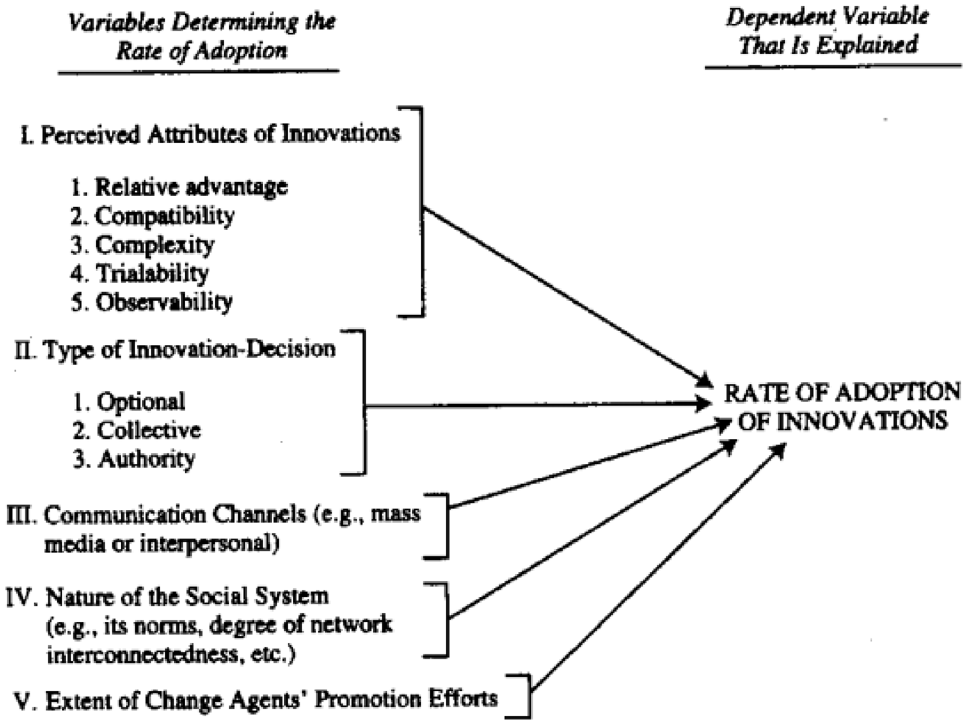


Figure 1: Variables Determining the Rate of Adoption (Hoffman, 2007, p. 43)

Rogers (1995) describes five perceived attributes of innovations[1]. Individuals perception of these attributes may affect its rate of adoption (Hoffman, 2007). Relative advantage refers to the degree to which an innovation is perceived as superior to the one it supersedes. Potential users have a need to understand why the new technology is superior to the old one. Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of potential adopters. Complexity describes how difficult an innovation is to understand and use, and negatively affects adoption. Excessive complexity will lead to a lower adoption rate. Observability relates to how visible the results of the

[1] See I on figure 1

innovation are to others. High observability positively affects adoption. Some technologies have benefits that are not easily recognizable. These technologies are harder to diffuse as users will not immediately see the benefits. A high observability will therefore increase adoption rates. Lastly, trialability is the degree to which an innovation may be experimented with, positively affects adoption. Users need to be able to test innovations. The process of trying out a new technology is a way to establish meaning of the implementation for the user, understanding how it works on a personal plane (Rogers, 1995). The importance of each attribute will vary with the type of technology we are dealing with. However, relative advantage seems to be a major determinant of a user's intention to adopt the technology. The complexity of the technology is classified as a barrier, however if sufficient incentive in the form of a relative advantage is in place consumers are willing to overcome complexity barriers.

Rogers' model is an excellent descriptor of which factors increase the adoption rate of a new technology; we have also determined the various phases of adoption. Rogers' focus is largely on a societal diffusion of a technology. Further, we will examine individual factors for adoption using the 1989 technology acceptance model.

2.1.2 Technology acceptance model

Introducing a technology and making people use that technology is two different things. The technology acceptance model (TAM) (Davis, 1989) argues that perceived usefulness and perceived ease of use are key factors in adopting new technologies. This means that in order to adopt a technology people will make a judgement on whether this technology is going to make their life easier (perceived usefulness) and if it does whether it is going to be a so hard to use as to negate the benefits (perceived ease of use). In the work perceived usefulness is defined as "*the degree to which a person believes that using a particular system would enhance his or her job performance*" (Davis, 1989, p. 320). Perceived ease of use is defined as "*the degree to* *which a person believes that using a particular system would be free of effort*" (Davis, 1989, p. 320). These two factors together strongly influence *an intention to use*. Even though the model uses intention as a dependant variable, there is reasonable evidence to suggest that intended behaviour generally leads to actual behaviour (Sheppard, Hartwick, & Warshaw, 1988). After its introduction the model has emerged as a robust model of technology acceptance (Choi & Ji, 2015). The results have also been replicated (Subramanian, 1994). To make people use a given technology one therefore must influence the perception of usefulness and ease of use. Conversely will negative experiences or negative perception of usefulness and ease of use reduce rate of adoption. Even though TAM was initially developed to explain adoption of information technology it has been adopted to uses in other technologies such as automation (Ghazizadeh, Lee, & Boyle, 2012).

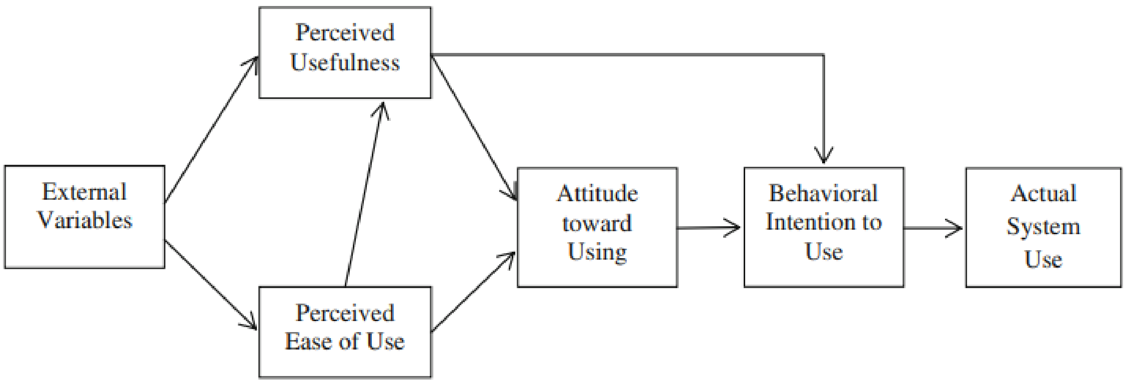


Figure 2 - Technology acceptance model (Ghazizadeh, Lee, & Boyle, 2012, p. 43)

After its introduction TAM has been further refined and expanded. Later works (Pavlou, 2003) introduced perceived risk and trust as additional factors. Trust influences the decision to adopt indirectly, through perceived risk and perceived usefulness as well as directly. However, trust is dependent on perceived risk to influence intention. From the model we can observe that the primary influencers on intention are perceived risk and perceived usefulness. Perceived ease of use is influential, but indirectly through perceived usefulness.

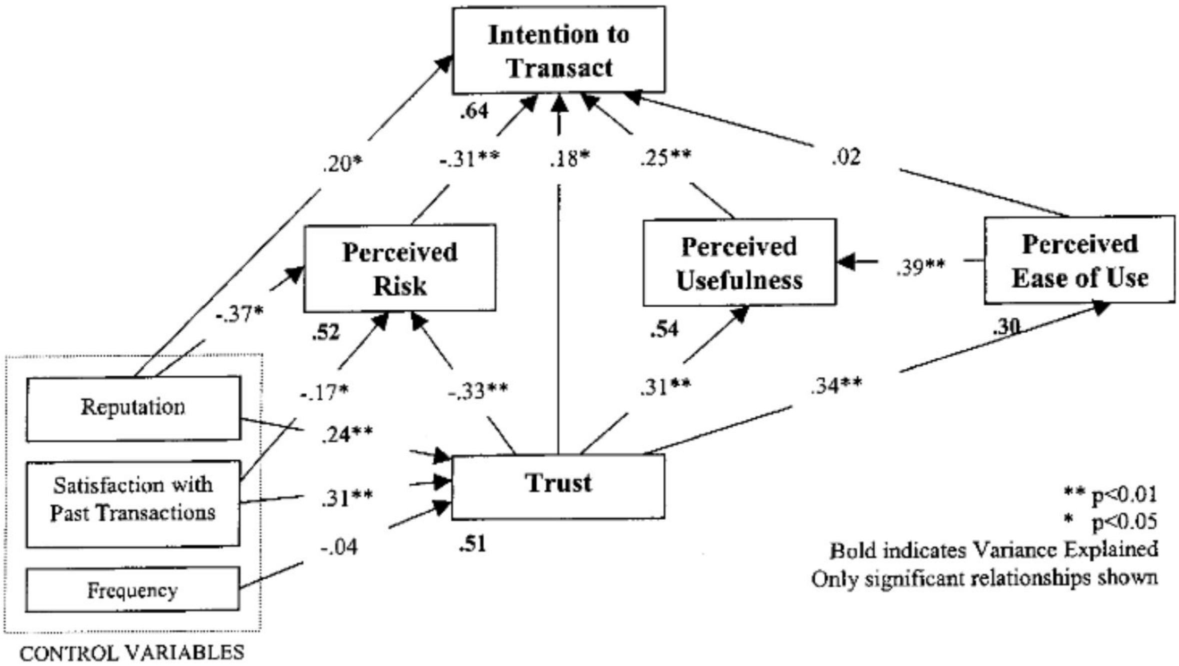


Figure 3 – Expanded technology acceptance model (Pavlou, 2003, p. 118)

Rogers diffusion theory has been connected to TAM. A study found that compatibility and relative advantage had significant positive effect on perceived usefulness. Complexity had a significant negative effect on perceived ease of use, while relative advantage and trialability had a significant positive effect (Lee, Hsieh, & Hsu, 2011).

2.1.3 Perceived risk

A common factor in both TAM and Rogers is perception. The advantage lies in the eye of the beholder. As such how an innovation is perceived quality is as important, if not more so than the actual quality. The same principle applies to risk. Risk can be divided between subjective and objective risk (Mitchell, 1999). Objective risk would be the risk that can be calculated from statistical models, and historical data and which will say something about the *actual* risk one can encounter in a specific set of circumstances. Subjective, or perceived, risk on the other hand is the level of risk the actor experiences when faced with the same set of circumstances.

The distinction is important since it is the perceived risk which drives an individual's decision making.

A development on the popular technology acceptance model is an inclusion of perceived risk as a factor on adoption – highly influenced by the trust of consumers. In innovation theory it is especially important given the inherent uncertainty related to new products. Perceived risk is given a high significance since it is a central determinant for adoption (Hegnstler, Enkel, & Duelli, 2016). In innovation literature perceived risk is mainly defined in terms of uncertainty about the possibility of the failure of a new product or the likelihood that the product will not work properly. The novelty of a new product will determine the degree of uncertainty surrounding perceived risk. Further, there is a significant gap in proven risk and perceived risk – likely attributed to a lack of trust. Trust has been shown to be essential in reducing perceived risk (Hegnstler, Enkel, & Duelli, 2016). This effect has also been examined in other works (Pavlou, 2003). The effect of trust on perceived risk is particularly pronounced in relation to automation technology. As a result, trust is indirectly a major determinant in user adoption.

Perceived risk is strongly influenced by the communication of a product actor. Building on Rogers theory of diffusion communication is seen as the main driver of perceived risk reduction and the acceptance of new innovations. Familiarity with a technology, through communication or experience, increases likelihood of adoption. The more radical and uncertain an innovation is, the greater the effect of familiarity on adoption. Rogers also described the factors of observability and trialability, both of which may reduce a consumer perceived risk. Insight into how an innovation works, and the ability to test it may increase the perceived reliability of the technology.

2.1.4 Perceived usefulness

Perceived usefulness and relative advantage are often used interchangeably, however there is a distinct difference between them. While perceived usefulness defines the way, a technology improves a users' effectiveness, relative advantage is used comparatively to other options. There is however a correlation between perceived usefulness and relative advantage. Users who experience a higher relative advantage also state a high perceived usefulness, however the opposite does not apply (Wang, Meister, & Wang, 2011). It therefore makes sense to use relative advantage in conjunction with perceived usefulness. Even though both perceived usefulness and ease of use are the two main factors of TAM, perceived usefulness consistently stands out at the main driver of technology adoption (Choi & Ji, 2015).

Trust influences perceived usefulness to a large degree (Choi & Ji, 2015). This indicates that utility alone is not enough for adoption if the adoptee does not trust the innovation. It further underscores the importance of subjective perception over objective performance. Trust can be assessed along three dimensions – ability, benevolence and integrity (Mayer, Davis, & Schoorman, 1995). These dimensions are interpersonal, but they can be mirrored in trust in similar aspects in *systems* (Thatcher, McKnight, & Arsal, 2011). Functionality is the belief that the system will provide the capabilities or functions that is asked of it. This is like competence or ability. Helpfulness refers to the belief that the system will provide aid if required. It mirrors benevolence in interpersonal trust. Finally, predictability, mirrors interpersonal integrity and is the belief that a system will act consistently. Consequently, instilling belief in functionality, helpfulness and predictability will have a large impact on perceived usefulness.

2.1.5 Passive innovation resistance

Innovations have failure rates between 30- 50% (Castellion & Markham, 2012), depending on the industry. Part of the reason why such a high percentage of innovations fail is due to passive innovation resistance. Consumers have an inherent resistance to innovations and must be presented with a compelling reason to adopt. This resistance can be either active or passive. Active innovation resistance represents a negative attitude formation driven by functional and psychological barriers that follows deliberate new product evaluation (Heidenreich & Kraemer, 2016). A passive innovation resistance on the other hand represents a predisposition to resist innovations due to an individual's inclination and to resist change and status quo satisfaction that already forms rather unconsciously prior to new product evaluation (Heidenreich & Kraemer, 2016). It is possible to overcome passive innovation resistance using a marketing strategy. The strategy should use mental simulation or benefit comparison, as it has been shown to be most effective (Heidenreich & Kraemer, 2016).

We have identified several drivers for adoption of new technologies, as well as barriers for adoption. The diffusion of innovations covers the societal diffusion of a new technology, while the technology acceptance model provides incentive for the individuals use of a new technology. We have also established an inherent resistance towards innovations. Further we will examine what actions decision- and policy makers can implement to further desired technologies.

2.2 POLICY ACTIONS TO INFLUENCE RATE OF DIFFUSION

2.2.1 Policy tools

In government there are various tools available that may be used to stimulate an innovation journey. We classify these policies into three categories: Regulations, Economic transfers, and soft instruments (Borrås & Edquist, 2013). These categories contain both incentives and disincentives in various forms.

Regulatory instruments shape the social and market interactions. Regulatory instruments are obligatory (laws etc), and companies need to follow them. Using these tools government can make the framework for interactions in the marketplace (Borrås & Edquist, 2013).

Economic transfers provide specific incentives for social and economic activities (Borrås & Edquist, 2013). Increased or decreased taxes, as well as subsidies and cash payments can stimulate or disincentivize certain behaviours.

Soft instruments make normative appeals to companies (Borrås & Edquist, 2013). Codes of conduct and campaigns are two examples, where government recommend and persuade actors into desired paths. Public-private partnerships is a more direct version of this approach.

Borrås & Edquist (Borrås & Edquist, 2013) argue that policy tools need to be tailored to each innovation challenge and its needs. Government need to identify low intensity innovation challenges and use available policy tools to increase the innovation intensity. Low intensity innovation is the problem in this situation, where private and public actors provide low intensity innovation. This is classified as an *innovation systems* problem.

2.2.2 Strategic niche management and transition management

We have identified several instruments policy makers can use to aid the implementation of innovations, however not all innovations have the same societal impact. While some are easy to implement, and their consequences are easily imagined; other are too radical compared to existing technologies and may have unforeseen consequences on the socio-technical level. Some innovations may require existing technologies to evolve and adapt to be integrated properly. In strategic niche management and transition management research measures are proposed to aid in the development and integration of such technologies.

Whenever new technologies are first developed, they are generally crude and inefficient. They do however hold promise and must be adapted to the uses they will ultimately serve. This problem is pivotal for many new technologies with sustainability promise for transportation (Schot & Geels, 2008). Strategic niche management (SNM) proposes a structured approach to deal with early-stage issues found in new technologies. Technological innovation is only one aspect of technology adoption and societal changes and societal goals should also be considered. SNM proposes the construction of niche spaces where technologies may experiment and develop unhindered. SNM is especially useful in particular types of innovations: "*socially desirable innovations serving long-term goals such as sustainability, and radical novelties that face a mismatch with regard to existing infrastructure, user practices, regulations etc*" (Schot & Geels, 2008, p. 539).

SNM works as a bottom-up process where technologies are developed in small niche projects and consequently conquer market niches once it is developed. The goal of SNM is a regime-shift where the old practices are replaced by the newly developed practice.

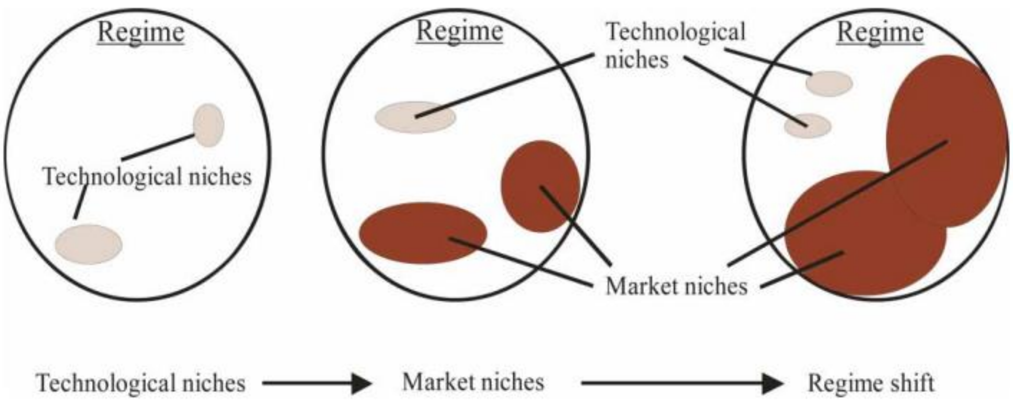


Figure 4: Progression of niches in SNM (Schot & Geels, 2008, p. 540)

The focus of SNM should be when creating networks of learning and development through sustainable innovation journeys. Policy makers guide these journeys, and Schot determine several key policy issues often dealt with in SNM. The technology push bias is one of the key issues, where drivers for a certain technology fail to symbiotically develop their technology alongside the societal changes that are connected to its development. Often research is focused merely on the goal of integrating a technology, without consideration for its societal consequences. Focusing projects on visions and guiding principles rather than technologies could help the co-evolution of social and technical change (Schot & Geels, 2008).

Transition management (TM) is an approach that is in many ways similar to SNM. TM is a governance approach based on the analytical perspective of society as a patchwork of complex adaptive systems. In order to improve and resolve persistent societal problems structural transformations or transitions are necessary (Loorbach & Rotmans, 2006). TM can be seen as a more top down approach than SNM in which development is to a larger degree sought channelled in a certain direction driven by a societal need. This means that TM typically is more applicable when looking at a sector or region over a given experiment or niche (Loorbach & van Raak, 2006). Transitions are complex in their nature with a multitude of actors and processes interacting. As such controlling transitions is hardly an absolute possibility. It is however possible to influence transitions, in both direction and speed (Loorbach & Rotmans, 2006). The basic steering in TM is anticipation and adaption. The process is set from a guiding macro-vision. The drive towards the macro-vision is built upon bottom-up, macro initiatives which influences the meso-regime. Goals of the vision is chosen by society and encouraged through active adaptive policy choices which furthers bottom-up growth. In TM, long-term visions can work to inspire social actors, if they are realistic about the innovation levels in the functional subsystem. Transitions are highly non-linear and can be divided into different phases. These phases have been described as the following (Loorbach & Rotmans, 2006) :

1. A **pre-development phase** where there is very little visible change at the systems-level but a great deal of experimentation at the individual level.
2. A **take-off phase** where the process of change starts to build up and the state of the system begins to shift because of different reinforcing innovations or surprises.
3. An **acceleration phase** in which structural changes occur in a visible way through an accumulation and implementation of socio-cultural, economic, ecological, and institutional changes.

4. A **stabilization phase** where the speed of societal change decreases and a new dynamic equilibrium is reached.

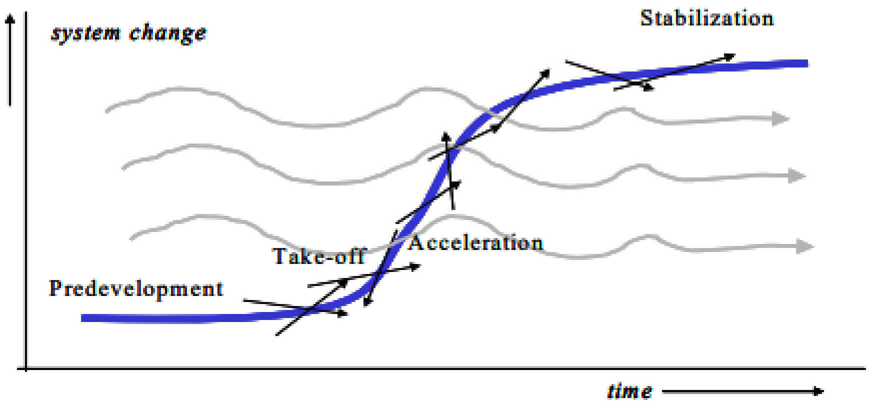


Figure 5 - : Different stages of a transition at different system levels (Loorbach & Rotmans, 2006, p. 4)

Local government and individual initiatives play the largest part in the predevelopment and take-off phase. Transition can be accelerated by dramatic events or crisis, but they cannot be caused by such events. SNM focuses on niche management while, TM focuses on system management. The two methods can complement each other. SNM could be used to foster potential innovations while TM could be used to do a transition management analysis to integrate an innovation more fully into the social system. TM can be used in the case of a societal problem to provide options that can then be explored through SNM. TM is strong in participatory processes, social learning, and agenda building. SNM is strong in development of specific innovation routes, technological learning and throughs on the organization of such a process (Loorbach & van Raak, 2006).

2.2.3 Introducing autonomous vehicles

Autonomous vehicles (AV) is a technology that allows vehicles to operate without a driver controlling the vehicle directly. AV is an automation technology and straddles between information technology, mechanical technology, and machine learning. Perhaps the closest existing example of similar technology is in autopilot systems in the aerospace industry. AV can potentially change mobility dramatically depending on the advancement of the technology itself and the degree of diffusion and adoption. Mobility is an area of society that influences many other areas and thus changes is complex and potentially system wide.

Perceived usefulness in the context of AV is a less researched subject. For AV buses its even less so. It is however reasonable to assume that perceived usefulness in traditional buses, has transferal value to AV buses. A study by Webb, shows the importance of reliability and the avoidance of negative experiences as particularly important in bus transport (Webb, 2010).

Perceived risk, and by extension trust, is also an important factor in TAM. In the AV context there are shown a general lack of trust in the technology (Shariff & Rahwan, 2017). In order to build trust, the importance of exposure and trialability is emphasized (Penmetsa, Adanu K, Wood, Wang, & Jones L, 2019).

3 EMPIRICAL CASE

3.1 DESCRIPTION OF ROGALAND AND ACTIVE POLICIES

Rogaland county is the 4th most populous county in Norway and consist of four major transport networks: Jæren, Dalane, Ryfylke & Haugalandet (Rogaland Fylkeskommune, 2017, p. 11). The population is mostly centralized along the coast of Haugalandet and in Jæren with the major cities of Sandnes and Stavanger. The region is mostly coastal, resulting in temperatures seldomly below freezing, however the coastal climate also results in heavy rains and winds. For a comparison the average precipitation in Rogaland is nearly twice that of Oslo (Andersen, Førland, Hygen, & Mamen, 2018).

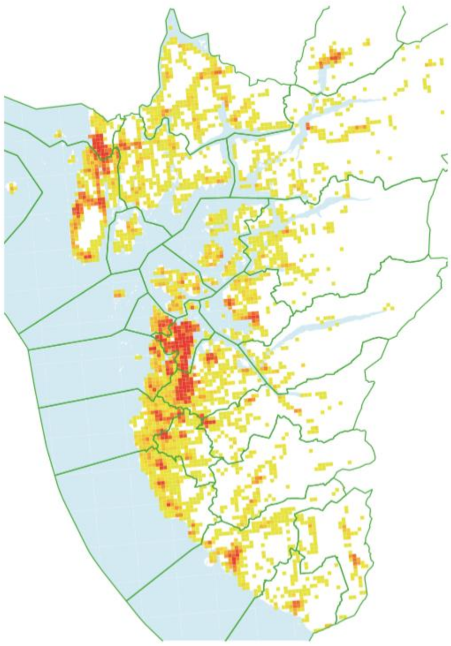


Figure 7 - Population density of Rogaland (Rogaland Fylkeskommune, 2017, s. 13)

The Rogaland county has a unified transport strategy for the region. It has a 10-year horizon and is a binding legal document for the county's work within transport. The goal of the strategy is for the municipalities within Rogaland county to have a coordinated plan for transportation (Rogaland Fylkeskommune, 2017).

Figure 7 displays the population density of Rogaland. The degree of urbanization varies greatly within the county, and as such makes an overarching transport strategy difficult. The Nord-Jæren area is more urbanized and with most workplaces being centralized in the Stavanger, Forus & Sandnes regions. In the southern parts of Jæren longer routes are required, and the population is de-centralized.

In conjunction with the transport strategy Rogaland Fylkeskommune issued a 5-year public transportation plan for Rogaland. It lays out several goals and guidelines for the public transport system in Rogaland. It cites effectivity, accessibility, safety and environmentally friendliness as key goals for the region (Rogaland Fylkeskommune, 2018, p. 29). There is a political goal where the public transport alongside walking and cycling should handle the increase in personal transport in Norwegian urban areas in the future. A zero-vision for injuries and fatalities in traffic was politically ratified by the parliament in 2002, (Statens Vegvesen, 2020) and Rogaland has seen a reduction in traffic accidents since the implementation of this vision by roughly 50% (Statistisk Sentralbyrå, 2020). Additionally, the signing of the 2017 "Byvekstavtale" aims for zero-growth in personal transportation by car and cites less emissions as the main motivation, with an improvement in personal mobility solutions as a motivator for change (Rogaland Fylkeskommune, 2017).

The plan discusses bus, trains & ferries across Rogaland, and lays the framework for investment into mobility solutions. Unique to Rogaland is the categorization of mobility solutions rather than merely public transportation, which allows for the planning of walking and cycling routes in conjunction with the public transport system. Currently Kolumbus is the mobility provider for the region.

In 2018 the total budget for the Rogaland public transport system was 822MNOK (Rogaland Fylkeskommune, 2018, p. 10), an increase by 45% since 2010. There has been a large effort put into increasing the standards of busses and bus-materials, as well as the development of new routes in specifically the Nord-Jæren region. The county guides an increase in travels per year by 5% in Nord-Jæren, and 3% in Dalane, Ryfylke & Haugalandet, respectively. This is to meet growing public transport demands and address the goal of absorbing all personal transport growth by public means rather than personal cars. A yearly increase will necessitate further investment.

In regards to new technologies, the current strategy encourages investment in new technologies that may add value for customers, be relevant for customer needs and improve public transport (Rogaland Fylkeskommune, 2018, p. 7). Autonomous buses are specifically mentioned, and a pilot project for autonomous buses has been on-going in the Forus business cluster since 2018 after the government signed legislation allowing for autonomous test vehicles in the Forus area. The project is limited in scope with the buses being restricted to a 20 km/h speed, and mainly acting as a short-distance shuttle between businesses (Mobility Forus, 2020). The bus includes a host which has control of the bus should it be necessary; it also follows a pre-planned route. Kolumbus cites "first and last" mile as the most probable uses for autonomous vehicles (Kolumbus, 2020). This concept is when the autonomous vehicle gets you to and from another long-distance transportation solution, such as a train.

Currently other municipalities looking into employing autonomous buses to solve their mobility needs. Forus PRT has made a report on the feasibility of two different routes in the Klepp municipality (Forus PRT, 2017)[2]. The report also discusses whether the speed limit should be 25 km/h or 35 km/h, and recommends 35 km/h. The report states that the speed limits are a safety precaution and acknowledges that a higher speed increases the severity of accidents. The rest of the report goes into technical details on the numbers of potential passengers observed, the likelihood of the bus being passed on higher speed limit roads, and the relative advantages and disadvantages of the two proposed routes.

3.2 CURRENT CHALLENGES FACING PUBLIC TRANSPORT IN ROGALAND

While large investments have been going into the public transport system over the last decade, the public perception of the services has stayed at low levels. In fact, when surveyed most residents in Rogaland believe they have worse access to public transport then they

[2] Appendix B

actually do (Rogaland Fylkeskommune, 2018). Kolumbus cite troubles with the integration of electronic tickets and unexpected downtime as the major reasons for a poor reputation among the users. However, these claims are based on a rather dated analysis from 2008 which claimed that the offering is better than the perceived offering (Rogaland Fylkeskommune, 2018, p. 9). No such comprehensive survey has been done since then, although there have been travel habit and perception surveys – none of them compared it to the actual offering.

Impression of Kolumbus								
Year	N	Don't know	1 - Very bad	2 - Bad	3- Neutral	4 - Good	5 - Very good	Average
2019	2827	7 %	5 %	8 %	32 %	35 %	12 %	3,4
2018	3215	10 %	10 %	11 %	28 %	27 %	13 %	3,3[3]
2017	2848	5 %	6 %	12 %	33 %	31 %	12 %	3,3
2016	2810	9 %	8 %	12 %	31 %	29 %	10 %	3,2

Table 1 - "Inntrykk of Kolumbus" translated (Appendix A)

Kolumbus organizes a public survey every year. Parts of the results of this survey has been made accessible for use in this thesis (Appendix A). By observing "Inntrykk av Kolumbus", we can see a yearly improvement in the overall perception of Kolumbus by 0.1 every year (on a scale of 1-5).

In the 2018 national travel habit survey 35% of respondents from Nord-Jæren answered that they have "bad" or "very bad" access to public transport (Statens Vegvesen, 2019). The survey also states that only 10% use public transport as their main method of transportation. This is lower than other urban regions, with Bergen and Oslo having 15% and 23% respectively stating that they use public transport as their main mode of transportation. There is not comparable data for the entire Rogaland region, however Nord-Jæren is the most urbanized part of Rogaland and most comparable to Oslo and Bergen. Oslo and Bergen also have more varied public transport options, with a tram solution in Oslo and a light rail in Bergen. A light rail

[3] By correcting for "Don't know" answers and running the averages, it seems to be an error in the average for 2018. The correct value should be 3,2.

solution was discussed in Nord-Jæren as well, with the government opting for a dedicated bus road instead.

4 METHODOLOGY

4.1 SCENARIO ANALYSIS

In the design of the thesis we base our methodology on scenario analysis. Some writers will argue that it is impossible to predict social phenomena, but we lean on the work of Petter Næss (2004) that shows that even if the future cannot be predicted with certainty there is still value to be gained by predicting likely consequences. Scenario analysis is given a thorough description by Koskow & Gaßner (2008). This work will serve as our main source on the methodology. We will also compare this with methods described in Nenseth, Ciccone & Kristensen (2019).

The question we want to examine deals with possibilities in the near future. As such not many methods are appropriate to use to give an informed answer. In social sciences one method to use in such events are scenario analysis. Scenario analysis cannot give exact answers but rather seeks to establish a range of plausible outcomes given a set of conditions. The future is by its nature uncertain and developments may or may not follow previously established patterns. The complexity of possibilities does also make other methods less appropriate to use. Most methods focus on observing or describing past events and are a such poor ways to gleam insight into the future.

A scenario is defined by many authors[4] as:

– a description of a possible future situation (conceptual future)

– including paths of development which may lead to that future situation

[4] From Koskow & Gaßner (2008)

In making a scenario one is not describing the future, but rather *a* possible future. We will develop 4 different scenarios based on different developments in certain criteria.

Scenario methods are used in the construction of different possible models of the future; their purpose is to generate a body of orientational knowledge which can serve as a compass for lines of action in the present (Kosow & Gaßner, 2008, p. 13).

We will use the 5 phases associated with scenario construction, as described in Koskow & Gaßner (2008, p. 26)

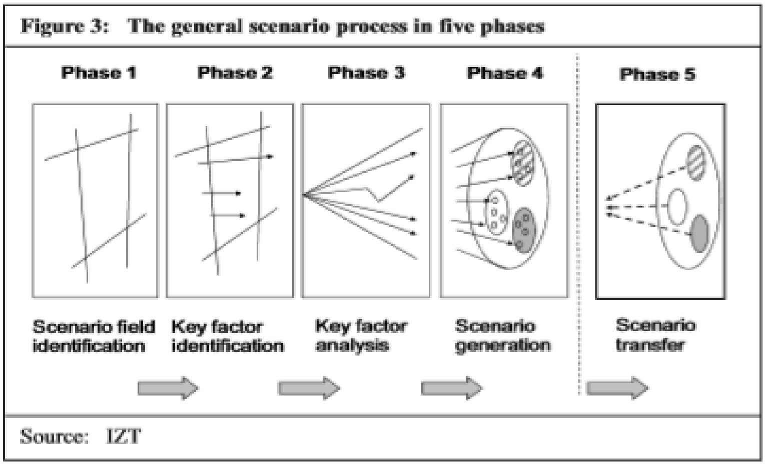


Figure 8- Scenario Funnel illustrated (Kosow & Gaßner, 2008, p. 24)

1. **Identification of the scenario field**

In the first step we define the purpose of our scenarios. The topic of the study and the problem we are dealing with. This phase sets the perspective for the period under study.

2. **Identification of key factors**

Identifying the descriptors of our scenarios. Empirical and theoretical analysis is required to establish a sound theoretical foundation for each scenario.

3. **Analysis of key factors**

Key factors are analysed to find what future characteristics are conceivable. Includes visualization of the future development of each key factor.

4. Scenario generation

Major bundles of key factors are brought together to create individual scenarios.

5. Scenario Transfer: Strategy assessment and development

Further processing of the scenario. Here the consequences and impacts of the scenarios are evaluated from a strategic viewpoint.

From this basic approach to scenario creation there exists several techniques to go from factor analysis and into scenario generation. In this case we have chosen a creative-narrative scenario technique. This kind of technique is used in normative scenario and within the context of explorative techniques (Kosow & Gaßner, 2008). In this technique we will identify two key factors with reference to their major values, resulting in a grid of two times two scenarios. While this is a somewhat simplistic approach, it allows to explore all permutations and to give a good overview of the basic positions.

4.2 DATA AND DOCUMENT ANALYSIS

Document analysis is a qualitative research method where topics are assessed by analysing relevant documentation such as business- or policy plans. A detailed document analysis has been conducted into the policy documents driving the implementation of AV technology in Rogaland, as well as the long-term development goals of the region. These will form the base of our discussion. Further, we have obtained the results of a survey conducted for Kolumbus by Epinion[5] which maps out customer satisfaction with the company. This data is significant due to Kolumbus being the main supplier of public transportation in Rogaland. We do not have

[5] Appendix A

the raw data so further analysis is not possible, however the results submitted to us will be used in our policy discussion. We have also obtained a report from Forus PRT[6] to the municipality of Klepp[7] showing potential routes and utilization of AV buses. This data is valuable because it gives insight into ongoing policies and shows that the scope of local projects is growing. The report also goes into details on how different speed limits is going to influence local traffic patterns.

4.3 BIASES / WEAKNESS

There are several weaknesses to the application of scenario analysis that one needs to be aware of when using it in scientific studies. A scenario analysis shows one or more versions of the future, not a single certain outcome. The goal of scenario analysis is to show possible developments of a certain subject or topic. The selection and construction of scenarios always implies that other scenarios could have been constructed and selected (Kosow & Gaßner, 2008).

Another limitation is in our own predictive capabilities, and in our capacity for visualizing the unknown and uncertain (Kosow & Gaßner, 2008). Scenario analysis has the risk of running down known paths, where the researchers display little innovation and overlook the presence of inconsistencies and the possibilities of less likely developments (Kosow & Gaßner, 2008). Mietzner discusses another form of our cognitive shortcomings. A common bias could be that researchers adhere to “black and white” scenarios, or the most likely scenario in the form of wishful thinking (Mietzner & Reger, 2005).

Despite decades of discussion on AV technology and rapid advances in the technological field, most of the research is confined to simulations and predictions. The lack of real-world data

[6] Recently changed name to Forus Mobility
[7] Appendix B

with the added variables that comes from a complex real-world environment is going to weaken any attempt to predict the impact of AV going forward.

5 SCENARIO CONSTRUCTION

The purpose of our scenarios is to give insights into which policy tools can be used to further the implementation of AV technologies into the Rogaland public transportation system. The results should guide policy makers who aim to implement autonomous technologies. Ideally the results should give insight into which category of policy action could be influential, and specifically relate these to real world policies. Currently AV technologies are restricted to small pilot projects with limited capabilities, the scenarios should imagine plausible developments of the current technological climate.

Our key factors for AV adoption are based on the adjusted TAM model (Davis, 1989) with perceived usefulness and perceived risk as our main determinants for adoption. We will investigate specifically how various policy actions may affect consumers perceived risk and perceived usefulness. It is important for the scenarios to be realistic and in the short-term will need to adhere to the current policy measures as well as the vision and sustainability models of the region.

5.1 KEY FACTOR: PERCEIVED USEFULNESS

Perceived usefulness has a positive correlation with rate of diffusion (Davis, 1989). To increase diffusion perception of usefulness needs to be increased. What constitutes perceived usefulness in AV technologies is not inherently clear. From the findings from Webb (2010), we can extrapolate what is the major determinants for public transportation, both in general and more specifically when it comes to bus transportation. By this logic perceived usefulness constitutes features which reduce errors, increase reliability, and increase the speed of public transportation. The perceived usefulness of an autonomous bus would be features which solve these problems. Policy measures which may limit an AVs capability in these areas, such as speed limits would be detrimental to the perceived usefulness from a customer perspective. It is also stated that increased trialability of new technologies may lead to an increase in relative advantage as well as a reduction in perceived risk (Rogers, 1995) (Davis, 1989). Trust is cited as a major factor within perceived usefulness (Choi & Ji, 2015), and Webb states that in a public transportation context small errors from the side of the bus service may have large effects on a user's future trust and loyalty of the service. Trust in perceived usefulness from a public transportation point of view may therefore be classified as a matter of reliability. Where a user's effectiveness in this case is the capability of the user of reaching from point A to point B in a timely and, most importantly, predictable manner.

Currently there is an adverse attitude towards public transportation in the Rogaland area, as shown in the county policy report on public transport (Rogaland Fylkeskommune, 2018). If the attempt to rectify the public image and/or improve the service quality succeeds it is reasonable to assume that the perceived usefulness of public transport will increase. An increase in the perceived usefulness of public transport in general might lead to an increase in perceived usefulness of AV buses.

Increases in adoption in other regions may increase perceived usefulness in AV technologies as well as increase public demand should the experiences be positive. On the other hand, negative experiences with immature technology can give a negative impression of perceived usefulness.

The rate of technological development will also influence perceived usability. Currently AV technology is in its infant stages and there are major technical obstacles still in the way before vehicles can be used autonomously all the time. As such the perceived usability is also limited by technological development. There is a substantial difference in estimations on when AV technology will mature, with some estimates as low as mid-2020s, and others as high as 2050 and beyond.

5.2 KEY FACTOR: PERCEIVED RISK

Increased perceived risk will decrease the rate of diffusion (Pavlou, 2003). Any activity carries with it a certain amount of objective risk. Transportation typically quantifies objective risk in injury per travelled unit of distance. Physical injury is not the only form of risk, however. Risk entail any chance of loss experienced by the user (Mitchell, 1999). As such getting delayed is another risk inherent in a transportation system. These kinds of objective risks can be measured in reliability metrics such as percentage of travels without delay or technical failure rate of vehicles.

Objective risk in the context of physical safety of autonomous buses, is likely to be initially be lower than for buses with human drivers, however potential systemic risks may be introduced (International Transport Forum, 2018). If AV aims to utilize its full potential it will be required to introduce larger and more complex systems of interaction between different AVs. More complex systems typically introduce more risk, which must be accounted for. There are several ways to handle such risk. Examples can be quality standards, and certification requirements on operators. The aerospace industry can serve as a blueprint for test and evaluation before making technology commercially available. An alternative can be to give developers more leeway but enforce stronger liability in the event of mishaps or accidents. Depending on which mitigating actions are taken objective risk could increase, decrease, or remain the same.

Subjective risk can take many forms when it comes to AV in public transit. Subjective risk is easier to measure than objective risk and is ultimately the determinant when it comes to human behaviour (Mitchell, 1999). Less trust leads to increased perceived risk. An article in Nature Human Behaviour suggest that the biggest roadblocks to adoption of autonomous vehicles is psychological (Shariff & Rahwan, 2017). In the article a study shows that 78% of Americans fears riding in an autonomous vehicle and only 19% trusting such a vehicle. Given that trust is fundamental to both perceived risk, and benefit, such a low confidence shows that increasing trust has a lot of potential to improve both perceived risk and benefit and thus increase rate of adoption.

In transportation there exists a potential for severe personal physical harm. A serious accident involving an AV bus is likely to greatly increase perceived subjective risk for users. When the first traffic fatality involving Tesla's, autopilot occurred in May 2016 it was covered by every major news organization (Shariff & Rahwan, 2017). Such a negative event early in adoption could significantly delay adoption (Loorbach & van Raak, 2006). Consequently, safety must be a major concern for policy makers to safeguard public trust in AV technology. Communication around safety and safety measures will be important given the gap between perceived risk and objective risk and may help reduce that gap.

Reliability is another factor tied to perceived risk. As risk is any kind of loss, or fear of loss a consumer experience. In public transit, this means loss of time or failure to meet appointments. It can even mean increased discomfort from waiting outside in the rain (Andersen, Førland, Hygen, & Mamen, 2018). A natural assumption is that as technology matures, reliability will increase. However, AV is likely to introduce complex systems of intercommunicating vehicles. This increasing complexity could have an adverse effect of reliability at least until these more complex systems mature as well (International Transport Forum, 2018).

According to a study conducted by (Penmetsa, Adanu K, Wood, Wang, & Jones L, 2019) trust is significantly affected by the ability of the public to gain first-hand experience with new technologies through, for instance, pilot projects. A reduction or increase in pilot projects or a change in the criteria in which these projects operate will expediate or reduce this development.

Some lack of trust can be attributed to the lack of legislation as to the responsibility of liability in the context of AV (Shariff & Rahwan, 2017). In the event of an accident, a programmed vehicle, will have some sort of ethical trade-off built into its programming. There must be a weighing of protecting the passengers of the vehicle as opposed to protecting the environment outside the vehicle. If clearer legislation is passed concerning these matters it can help increase trust and thus increase the rate of diffusion. At the time of writing this field is largely unfilled in legislation.

5.3 ANALYSIS OF EFFECT OF ACTIVE POLICIES ON KEY FACTORS

The Rogaland area currently has several active policies regarding the adaptation of autonomous vehicles. A limited number of these are of local origin. Most importantly, legislation regarding the legality of autonomous vehicles are decided at the national level. Examining different policy documents, we have identified the following three active policies originating from the local government in Rogaland: speed limits, trial areas and the local pilot project.

Assessing the impact of these policies on key factors determining diffusion will allow for construction of scenarios considering altering or removing these policies.

5.3.1 Speed limits

Currently (2020) usage of autonomous vehicles in Norway is on a trial basis. For each use one must apply for a time-restricted permit. With each such a permit comes a set of speed restrictions. These restrictions are in place even on roads which has a higher general speed limit. The consequence is that autonomous vehicles can presents an obstacle to ordinary traffic. A reduced speed limit will influence perceived usefulness through a decrease in effectiveness compared to alternative modes of mobility. A public image of autonomous vehicles as perceptibly slower than alternative modes of mobility may have a negative impact even beyond actual reduced effectiveness if it becomes associated as a secondary form of transport. In other words: as the benefits of the technology become less apparent the observability is negatively affected which in turn hinders diffusion (Rogers, 1995). A negative public image will have a negative impact on trialability as fewer people will consider the form of mobility. Reliability should remain relatively unaffected by speed limitations unless they become so low as to make it difficult to keep a given schedule.

Enactment of speed limits is one way to reduce objective risk in an immature technology. The consequences of accidents increase with speed. A restrictive policy regarding speeds will therefore ensure that the severity of potential accidents is reduced. In the Rogaland area, different speed limits are set depending on the technology being used, and the area the bus is meant to be used in. One proposal shows 25 or 35 km/h as alternatives for such a limit (Forus PRT, 2017). The speed limits are below contemporary traffic, but in some cases are close to them. These speed limits mean that there are roads where AV buses are not suitable which put limitations on the amount of visibility they get. In sum, while speed limits help reduce perceived risk, it also serves to limit the reduction in perceived risk by limiting trialability.

5.3.2 Local trial areas

To assess the use of technology in a real-world environment, trials will have to be conducted. In the Rogaland area, a part of an industrial zone has been opened to trials together in conjunction with regular traffic. One alternative would be to assign closed-off areas for real-life testing of autonomous vehicles, another alternative would be to allow AV unrestricted access to the public road network. Establishment of trial areas is a way to ensure potential increased risk is confined to designated areas where this risk is considered acceptable. It can be seen as a consequence reducing measure. The intermingling of autonomous and non-autonomous traffic allows the technology to be tested and evaluated for use in a larger context.

The availability of such areas allows for more accurate testing and feedback that running simulations. As time progresses, the data and experiences from these testing areas will increase the reliability of autonomous vehicles. It will also be possible to apply data from these test areas to other places, both nationally and internationally. The Rogaland area also provides test areas that has an environment that is prone to sight reducing precipitation and cold surfaces, making it unusual compared to California which has seen more test projects so far. Having the test areas in public and intermingled also increases trialability. Although the scope of the trial area has been limited, other test and operating areas have been considered. Other municipalities are also currently considering attracting autonomous vehicle testing or deployment (Forus PRT, 2017) (Jupskås, 2018). We imagine future developments where the degree of trialability is varied through the intensity and availability of trial areas for AV buses.

5.3.3 Pilot-project

To facilitate safe testing of autonomous vehicle technology policies have been enacted in the country to allow for pilot-projects on an application basis. As a result, a public-private partnership has been established in the Rogaland area. This project is granted a trial permit for autonomous buses. The possibility of testing the technology in a real-world scenario and with the actual public. This policy helps increase trialability which in turn helps reduce perceived risk.

The pilot-project as an initiative allows for increased experience on the operation of autonomous vehicles and seeks to bring hands-on experience to public transportation users. Further, a goal of the current pilot project is to facilitate itself as a national hub for the testing and development of autonomous vehicles (Mobility Forus, 2020). There are no formal restrictions on the pilot projects from a national scale. However, they must abide to the grants given by local government when a project is greenlit. In practice constraints on the projects are enacted on the knowledge of local government and the capabilities of current technology. Potentially, restrictions can be lifted as the technology matures and user confidence grows. Currently the initiative sets a platform for the trialability of AV technologies to consumers. From diffusion theory we know that trialability is a key factor in the perceived usefulness of new technologies (Rogers, 1995), as consumers need hands-on experience with new technologies to realise their potential. We also know that increased trialability may reduce the perceived risk of new technologies as well. The importance of exposure is shown to be highly relevant in multiple works (Shariff & Rahwan, 2017) (Penmetsa, Adanu K, Wood, Wang, & Jones L, 2019). However, this intermingling carries with it the risk of increasing perceived risk in the case of accidents or other unwanted or unintended events. If policy remains unchanged there will likely be a gradual reduction in perceived risk of AV technologies as more users gain exposure to the technology through the Forus area pilot project.

When it comes to the reliability aspect where users value preciseness and effectiveness of reaching their destination, it is unclear whether pilot-projects will directly increase the perceived reliability of the service. Increased trialability may affect the perceived reliability of the service as users get hands-on experience. This may be affected by the parameters under which the pilot-projects operate. Our assumption is that a strictly regulated pilot-project with conservative operating parameters may negatively affect the perceived reliability of the service, as users get a restricted experience of the service. The main advantages of the pilot-projects are the operating experience and technological understanding gained by the operators, as well as a familiarization of the technology with consumers.

5.3.4 Summary of effect of current policies

Factors	*Speed limits*	*Trial areas*	*Pilot-projects*
Reliability	-	+	+
Trialability	-	+	+

Table 2 Summary of effects of current policies on perceived usefulness

The combined effects of the current policies are summarized in the table above. Overall, trial areas and the pilot project will increase reliability and trialability while speed limits will serve to reduce reliability and trialability. Increase of speed limits can therefore help increase rate of adoption of autonomous buses.

5.4 POTENTIAL NEW POLICY ACTIONS

Most relevant factors affecting perceived risk is the observability and trialability of the technology, as well as public trust in the technology (Rogers, 1995). In addition to the current policy actions there are several other soft instruments that policy makers may enact to drive innovation in a desired direction or increase the diffusion of an innovation. In 2.2 we discussed these instruments, and many of these are not currently enacted in the Rogaland region for AVs. Financial instruments such as tax incentives may still be enacted and could seek to increase investment in a desired technology. Additionally, regulations can be implemented to expediate the adoption of autonomous technologies. With the public transport network being wholly controlled by the county government, it is quite possible to simply enact a required minimum limit for autonomous usage. Enacting such minimum limits can help create niche environments where technology can develop according to SNM. From these niche environments more robust technology can emerge, and a broader diffusion can take place.

A wider adoption of SNM could spark further innovations in the county. Granting protected niches from which technologies can emerge could potentially also have positive effects on other parts of society. In the context of AV, these protected niches are the breeding grounds form which the technology can mature and compete against incumbent technologies on a more equal footing. At its core SNM is a bottom up approach and thus the degree to which the emerging solutions fit policy goals will vary. It might therefore be possible once the technology is accepted past the pre-development phase to change to transition management. This would give the region more control of the diffusion. Adopting transition management will unify the emerging solutions under a common policy vision and the ones supporting the vision could be enhanced while the niches not in support could get less protection. However, the county acknowledges the difficulties in obtaining and maintaining the competence to keep up with the technological development (Rogaland Fylkeskommune, 2017), so it might not be feasible from a resource standpoint.

Subjective perceived risk may effectively be reduced by policy actions which shift the discussion to the actual objective risk of automated vehicles compared to traditional transportation (Shariff & Rahwan, 2017). Users may overly focus on the particularities of the new technology, especially regarding the logical decision making of the vehicle – when the objective risk is lower than a traditional vehicle. Another potential action by government is to offer high-visibility, low cost gestures that do the most to assuage the public's fear (Shariff & Rahwan, 2017). Lastly, policy makers should resist to put in overly strict restrictions in response to accidents and mishaps.

5.5 SCENARIO GENERATION

Using creative narrative scenario technique, we are combining our two key factors and defining the major values as either a high case or a low case, resulting in four major scenarios.

To facilitate our scenario generation, we will determine future plausible developments of the perceived usefulness of AV technology. As perceived usefulness is tied to trialability and reliability, events or factors which will increase these will also increase perceived usefulness. An increase in privately owned AVs will help increase trialability, and thus indirectly increase diffusion of AV buses. As perceived usefulness and perceived risk is the most prominent factors to determine rate of diffusion, we will look at different combinations of development for these two factors. Going forward, each of them may turn higher or lower depending on events and policy actions. In the following table the different combinations are given a name and a further description of what each of the different scenarios might look like.

Scenario Combinations		**Perceived risk**	
		High	Low
Perceived usefulness	High	*Laissez-faire*	*Transformation*
	Low	*Resistance*	*Stagnation*

Table 3: Scenario combinations from development in factors

Scenario 1: *Laissez-faire* - High perceived usefulness, high perceived risk.

Our first scenario constitutes a strong development in the AV technology, and potential foreign influences leading to a high perceived usefulness. At the same time trialability may have been unchanged or lowered in our local region increasing perceived risk. Increased perceived risk could also originate from the removal or reduction in restrictions leading to more spectacular accidents and incidents. In such a scenario AV technology may have become high profile, not only locally but internationally, and widely discussed with faults and accidents taking the headlines in the discussions of the technology. Policy selections influencing this scenario may be an increase in pilot projects and trial areas. With large exposure there is also an increased risk that problems may occur, which could have an adverse effect on the perceived risk of the projects. Especially in public transportation we have established from the research of Webb (2010) that consumers are especially averse to problems affecting their travel. In Rogaland public perception of public transportation is already low as shown in the Kolombus surveys. While they are improving, we may assume an accident or major problem with these pilot projects could disproportionately affect perceived risk.

Scenario 2: *Resistance* - Low perceived usefulness, high perceived risk

The second scenario is where diffusion will be naturally at its lowest state. Accidents or controversies surrounding the technology is mixed with a low perceived usefulness from little exposure or failed pilot projects. In this scenario we expect a much smaller legislative and societal willingness to adopt the technology. Unless active steps are taken, diffusion will most likely remain low as aversion from perceived risk will result in less exposure to the technology, making sure perceived risk remains high. In this scenario, more active policies must be employed to compensate, not only for passive innovation resistance, but to mitigate active aversion to the technology. Policies of communication can be used, as well as necessary steps to keep objective risk acceptable if this is the cause of the elevated sense of perceived risk.

Scenario 3: *Stagnation* - Low perceived usefulness, low perceived risk

In our third scenario there are no breakthroughs in technological developments increasing perceived usefulness, alternatively trialability and pilot projects are small in scope leading to a small conversion of technological developments into perceived usefulness. Alongside this development perceived risk remains low as the technology is not a widely discussed topic. This scenario may also be the result of a reduction in funding or altogether cancellation of trial projects in Rogaland. Another plausible road to this scenario entails restricting AV technology to the extent that perceived usefulness remains too low for users to consider it a viable mobility option. Additionally, too strict restrictions on the place of operation as well as other restrictions such as speed limits, passenger numbers may lead to a lowered perceived usefulness from users.

Scenario 4: *Transformation* - High perceived usefulness, low perceived risk

In our final scenario perceived usefulness is high, while perceived risk is low. This combination will produce the highest rate of diffusion. To achieve this scenario a high degree of trialability and effectiveness is achieved through a combination of technological advancement and supporting policy actions. Increased exposure decreases perceived risk, while prudent legislation keeps objective risk to an acceptable level. Regarding active policies, this means increasing speed limitations as much as possible without compromising safety. Widespread adoption allows for tapping into the full potential of AV technology further increasing perceived usefulness. Increased diffusion also allows for higher trialability driving diffusion even more by lowering perceived risk. A high perceived usefulness may also help overcome the negative reputation of local public transit by offering a new experience, further shifting transportation usage over to mass transit. A wide adoption in the Rogaland area, could provide a model for expansion and adoption in other areas.

5.6 Scenario transfer: Strategy assessment and development

Norway has a grand strategic goal of moving automobile users over on public transportation as well as walking and cycling to reach environmental objectives. We assume autonomous vehicles will play a role in the improvement of public transportation across the region. The discussion of our scenarios and the potential recommendations on future strategies will be under the assumption that a high level of diffusion is desirable. Rogaland Fylkeskommune together with four local municipalities has made an agreement with the Norwegian government that all growth in traffic from 2017 is to be done with mass transit (Rogaland Fylkeskommune, 2017). Even though this agreement expires in 2023 it shows the intention of attempting to increase the share of mass transit in the mobility mix. Rogaland has also developed a transportation strategy for 2018-2029 (Rogaland Fylkeskommune, 2017). In this strategy the goal of increasing the share of mass transit, especially for the more urban areas, are confirmed. This strategy further states that outside of the most urban areas, the primary aim of bus transportation is to facilitate usage of the rail-connections.

Looking at the four scenarios, the *Transformation* scenario, is the one which offers the highest rate of technology diffusion. This scenario is dependent on both active policies and positive developments of technology. Some of the active policies will have a resource requirement and if the ultimate goal is to increase the portion of the public that chooses public transport over cars, investment into adoption of AV technology isn't necessarily the most cost-effective solution. A lack of supporting policies or continuation of policies on their current levels are unlikely to result in a high level of technology diffusion given the current poor reputation of public transport and the existing passive innovation resistance. Adoption of a *Laissez-faire* scenario with removal of as much restrictions as possible to maximize perceived usefulness can be an alternative approach. This approach carries a potential to increase perceived risk and may ultimately lead to a lower rate of diffusion over time. Stagnation is likely to produce lower rates of diffusion than both *Transformation* and *Laissez-faire*. A lack of supporting policies could lead to the Stagnation scenario. A breakthrough in technology which increases perceived usefulness might turn a *Stagnation* scenario into a *Transformation* or *Laissez-faire* scenario. This breakthrough might come externally or be the result of renewed or increased use of supporting policies. The *Resistance* scenario offers the lowest rate of diffusion. In that scenario, it is likely that adopting supporting policies comes with increased political cost.

To facilitate diffusion, we wish to steer toward a transformation scenario where the perceived usefulness is high and perceived risk is low. The current pilot project in Forus has a speed limit of 24km/h while normal traffic runs at 60km/h. As discussed previously this is a matter of risk reduction, although it may also have an adverse effect when it comes to the perceived usefulness of the technology. There is a conflict between perceived risk and perceived usefulness. It is unclear at which point a reduction in speed limits would be advantageous, as we wish to reduce the chance of any incidents involving the vehicle.

Ultimately this should be a matter of objective risk as determined by experts in the field of automation, however the public discussion surrounding risk should be adhered to. As discussed in our literature review, a transitionary measure in this case would be to shift the discussion surrounding the technology from subjective to objective risk. An alternative to a transition out of restrictions could be to have dedicated roads for the buses where other traffic and pedestrians are less of a concern. In such an environment buses could potentially operate at higher speeds with a similar perceived risk.

As the technology has yet to be fully commercialized, we define it as a pre-development/early take-off phase where the technology is still under development and not yet suitable for conquering technological niches. In this phase the coordination of pilot project development is important. One option is for Rogaland itself to coordinate several trial projects of its own within the Rogaland region. Possibly an increase of speed limits or servicing different demographics could be tested in locally in Rogaland. Another option is for Rogaland to coordinate with larger national or international test projects; there are already other autonomous projects in Oslo. A coordination effort would be beneficial, to share best practices and avoid having to reinvent the wheel. As the socio-technical level evolves it is important for the Forus project to implement lessons learned from other regions; especially if the long-term goal is for the system to be more widely deployed in the region. Currently there are no official knowledge sharing between Forus Mobility, the Rogaland autonomous solution supplier, and Nobina – the Oslo supplier. The Oslo project has a slightly different restriction with a speed limit of only 12km/h.

6 DISCUSSION

Our original problem statement looks at how policy selections may influence the diffusion of AV technologies in Rogaland. Through our scenario analysis we have combined theoretical knowledge of diffusions with our empirical case and gained insight into four scenarios of future developments on the key factors affecting diffusion. Our thesis is unique in its combination of traditional diffusion theory on autonomous vehicle technology. While this thesis suffers under a lack of data, the combination of theory with technological and regional context may produce guidance on further research. An identification of fundamental drivers can help identify appropriate policy responses, but further research would be necessary to give quantifiable results. The strength of the proposed key factors needs to be further tested in a real-world environment to quantify their effects. Further, our scenarios are only four of many possible developments that may occur in the future and there are many other effects that could have an impact on how the diffusion of AV technology transpires.

The implications of our findings should affect which key factors policy makers should focus on when autonomous vehicle technology is to be developed and implemented. We have also identified trust as a major factor affecting both perceived usefulness and perceived risk. Given available data shows trust in general to be low, this is an area which would be very interesting for future research. A low level of trust could also indicate a greater gap between perceived risk and objective risk. It would also be useful to examine if the gap between perceived and objective risk is greater for AV technology than for similar types of technology.

Reviewing our conceptual framework of scenario analysis there are some areas which could be strengthened if the framework is to be replicated in another thesis. The scenario generation process is excellent for maintaining focus and keeping the scenarios realistic. However, a weakness in the current methodology is a limit in variations on scenarios. With wider scenarios involving more factors, it would be possible to look at more drastically different and interesting scenarios. This could, however, also lead to a less focused thesis.

6.1 RECOMMENDATIONS

To reach the policy goal of increased usage of public transport using AV technology, the highest rate of technological diffusion should be sought. The *Transformation,* scenario offers the highest rate of the four presented through high perceived usefulness and low perceived risk. This entails maintaining the current policies but seek to increase the speed limits as high as possible without exceeding acceptable risk. Further enhancement should be sought through information sharing and the establishment of more niches to support the current technology. A more active usage of communication to increase trust in the technology would also likely increase rate of adoption given that the current level of trust is so low. Future introduction of policy should be evaluated against their effect on perceived usefulness, perceived risk, and trust.

7 CONCLUSION

The project was hampered by being conducted at the time of the COVID-19 epidemic. This epidemic made collection of primary data, and cooperation with different actors in the field more difficult than it could have been. As such, one weakness of the project is the limited access to primary data. Ideally more primary data would be used. However, time constraints and literal lack of available real world, primary data makes this impossible.

This project focus policies and their effect on buses and public transport within the sphere of AV mobility. Such a focus excludes one of the big potential developments of AV which is the individual AV transport. The reason for the exclusion is to keep the focus of the scope of the study.

Diffusion is a complex topic and examining the effects of such a system is by necessity fraught with simplifications. Despite this shortcoming, it can be useful to examine potential paths the future might take. Through a scenario analysis this thesis sought to examine introduction of AV technology. More specifically:

> *How can policy selection help influence an increased rate of diffusion of AV technology into public transit (PT) in the Rogaland region?*

The rate of diffusion of AV technology is primarily driven by perceived risk and perceived usefulness. These factors are in turn affected by the level of trust in the technology. Combining development in these different factors, has led us to produce four scenarios. In our thesis we recommend guiding toward the *transformation* scenario, where the rate of diffusion is highest. In this scenario policy selection will be crucial in encouraging technological development, while keeping perceived risk at manageable levels. The current policies enacted by the local government are likely to help increase diffusion and should be maintained or expanded. Additionally, strategic niche management may be used as a tool to further enhance technological diffusion. We encourage the creation of technological niches to grow technology to mature levels and adopt it system wide.

8 BIBLIOGRAPHY

Andersen, A., Førland, E., Hygen, H., & Mamen, J. (2018). *Climate Indicators for Norwegian travel behaviour - in present and future climate.* Norwegian Meterological Institute.

Borrås, S., & Edquist, C. (2013, April 12). The Choice of Innovation Policy Instruments. *Technological Forecasting & Social Change* .

Castellion, G., & Markham, S. K. (2012, October). Perspective: New Product Failure Rates: Influence of Argumentum ad Populum and Self-Interest. *The Journal of Product Innovation Management*.

Choi, J. K., & Ji, Y. G. (2015). Investigating the Importance of Trust on Adopting an Autonomous Vehicle. *International Journal of Human-Computer Interaction 31:10*, ss. 692-702.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. *MIS Quarterly*, 319-340.

Forus PRT. (2017). *Trase Autonom Buss.* Stavanger: Forus PRT AS.

Ghazizadeh, M., Lee, J. D., & Boyle, L. N. (2012). Extending the Technology Acceptance Model to assess automation. *Cogn Tech Work 14*, pp. 39-49.

Hegnstler, M., Enkel, E., & Duelli, S. (2016). Applied artificial intelligence and trust - The case of autonomous vehicles and medical assistance devices. *Technological Forecasting & Social Change 105*, pp. 105-120.

Heidenreich, S., & Kraemer, T. (2016). Innovations - Doomed to fail? Investigating Strategies to Overcome Passive Innovation Resistance. *Journal of Innovation Management*.

Hoffman, V. (2007, July). Farmers and researchers: How can collaborative advantages be created in participatory research and technology development. *Agriculture and Human Values*.

International Transport Forum. (2018). *Safer Roads with Automated Vehicles?* OECD.

Jupskås, S. H. (2018, Desember 17). *Et skritt nærmere førerløse Ålgård-busser*. Hentet fra Stavanger Aftenblad: https://www.aftenbladet.no/lokalt/i/VR7Q8l/et-skritt-nrmere-frerlse-algard-busser

Kolumbus. (2020, March 25). *Hvorfor selvkjørende?* Hentet fra Kolumbus: https://www.kolumbus.no/aktuelt/selvkjorende-buss/sporsmal-og-svar-selvkjorende/hvorfor-tester-kolumbus-selvkjorende-kjoretoy/

Kosow, H., & Gaßner, R. (2008). Methods of Future and Scenario Analysis: Overview, Assessment, and Selection. *DIE Studies, 39*.

Lee, Y.-H., Hsieh, Y.-C., & Hsu, C.-N. (2011). Adding Innovation Diffusion Theory to the Technology Acceptance Model: Supporting Employees' Intention to use E-l. *Educational Technology & Society*, pp. 124-137.

Loorbach, D., & Rotmans, J. (2006). Managing transitions for suistainable development. In X. Olshoorn, & A. J. Wieczorek, *Understanding Industrial Transformation - Views from different Disciplines* (pp. 187-206). Springer Netherlands.

Loorbach, D., & van Raak, R. (2006). *Strategic Nice Management and Transition Management: different but complementary approaches.* Discussion paper, permission obtained from the authors to quote (e-mail 17.04.2020).

Mayer, R. C., Davis, J. H., & Schoorman, D. F. (1995, July). An Integrative Model of Organizational Trust. *The Academy of Management Review, Vol. 20 No. 3*, pp. 709-734.

Mietzner, D., & Reger, G. (2005). Advantages and disadvantages of scenario approaches for strategic foresight. *Int. J. Technology Intelligence and Planning*.

Mitchell, V.-W. (1999). Consumer perceived risk: conceptualisations and models. *European Journal of Marketing Vol. 33 No 1/2*, ss. 163-195.

Mobility Forus. (2020, March 25). *Free Self Driving Bus at Forus*. Hentet fra Mobility Forus: https://www.forusprt.com/laer-mer-om-vare-selvkjorende-busser/?lang=en

Nenseth, V., Ciccone, A., & Kristensen, N. B. (2019). *Societal consequences of automated vehicles - Norwegian Scenarios.* Oslo: Norwegian Centre for Transport Research.

Næss, P. (2004). Prediction, Regressions and Critical Realism. *Journal of Critical Realism, 3:1*, ss. 133-164.

Pavlou, P. A. (2003). Consumer Acceptance of Electronic Commerce: Integrating Trust and Risk with the Technology Acceptance Model. *International Journal of Electronic Commerce*.

Penmetsa, P., Adanu K, E., Wood, D., Wang, T., & Jones L, S. (2019, September 19). Perceptions and expectations of autonomous vehicles - A snapshot of vulnerable road user opinion. *Technological Forecasting & Social Change 143*, ss. 9-13.

Rogaland Fylkeskommune. (2017). *Byvekstavtale mellom Rogaland Fylkeskommune, Stavanger, Sandnes, Sola & Randaberg Kommune og Staten.*

Rogaland Fylkeskommune. (2017). *Samferdselsstategi for Rogaland 2018-2029.* Stavanger: Rogaland Fylkeskommune.

Rogaland Fylkeskommune. (2018). *Handlingsprogram for kollektivtrafikken i Rogaland 2018-2023.* Stavanger: Rogaland Fylkeskommune.

Rogers, E. M. (1995). Diffusion of Innovations. I E. M. Rogers, *Diffusion of Innovations.* New York: the Free Press.

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda and policy. *Technology Analysis & Strategic Management 20:5*, pp. 537-554.

Shariff, A., & Rahwan, I. (2017, December 14). Psychological Roadblocks to the adoption of self-driving vehicles. *Nature Human Behavior*.

Sheppard, B. H., Hartwick, J., & Warshaw, P. R. (1988, February). The Theory of Reasoned Action: A Meta-Analysis of Past Research with Recomendation for Modifications and Future Research. *Journal of Consumer Research*.

Statens Vegvesen. (2019). *Nasjonal Reisevaneundersøkelse 2018.* Statens Vegvesen.

Statens Vegvesen. (2020, March 25). *Nullvisjonen*. Hentet fra Statens Vegvesen: https://www.vegvesen.no/fag/fokusomrader/trafikksikkerhet/nullvisjonen

Statistisk Sentralbyrå. (2020, March 25). *Statistisk Sentralbyrå*. Hentet fra Trafikkulykker med personskade: https://www.ssb.no/statbank/table/09006/tableViewLayout1/

Subramanian, G. H. (1994). A Replication of Percieved Usefulness and Percieved Ease of Use Measurement. *Decision Sciences*.

Thatcher, J. B., McKnight, D. B., & Arsal, R. E. (2011, February). The Role of Trust in Postadoption IT Exploration: An Empirical Examination of Knowledge Management Systems. *IEEE Transactions on Engineering Management, Vol. 58, No. 1*, pp. 56-70.

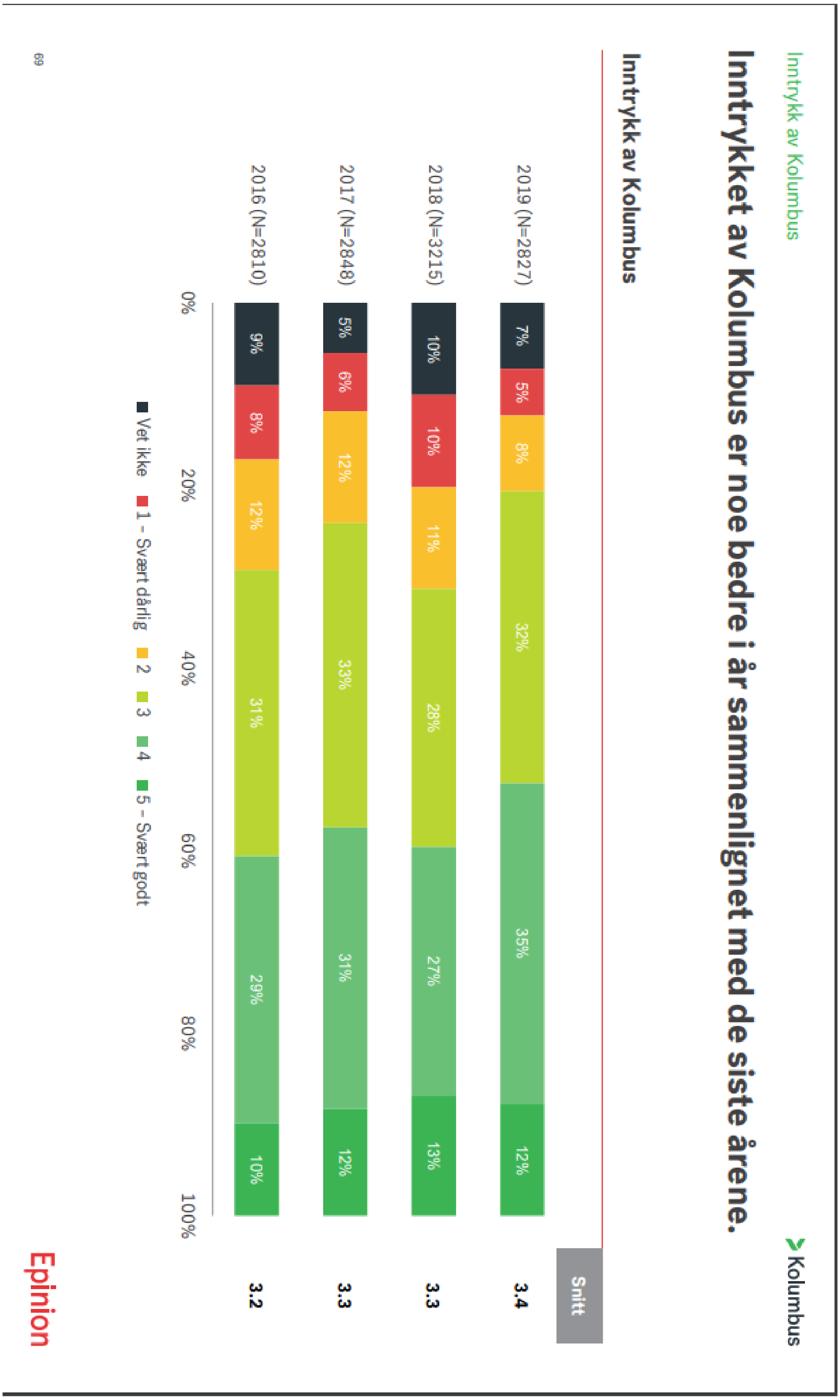
Wang, Y., Meister, D., & Wang, Y. (2011, Jan-March). Reexamining Relative Advantage and Perceived Usefulness: An Empirical Study. *International Journal of Information and Communication Technology Education*, ss. 46-59.

Webb, V. (2010). *Customer Loyalty in the Public Transportation Context* . Massachusetts: Massachusetts Institute of Technology.

Wejnert, B. (2002). Integrating Models of Diffusion of Innovations: A Conceptual Framework. *Annual Review Sociology*, pp. 297-326.

9 APPENDIX

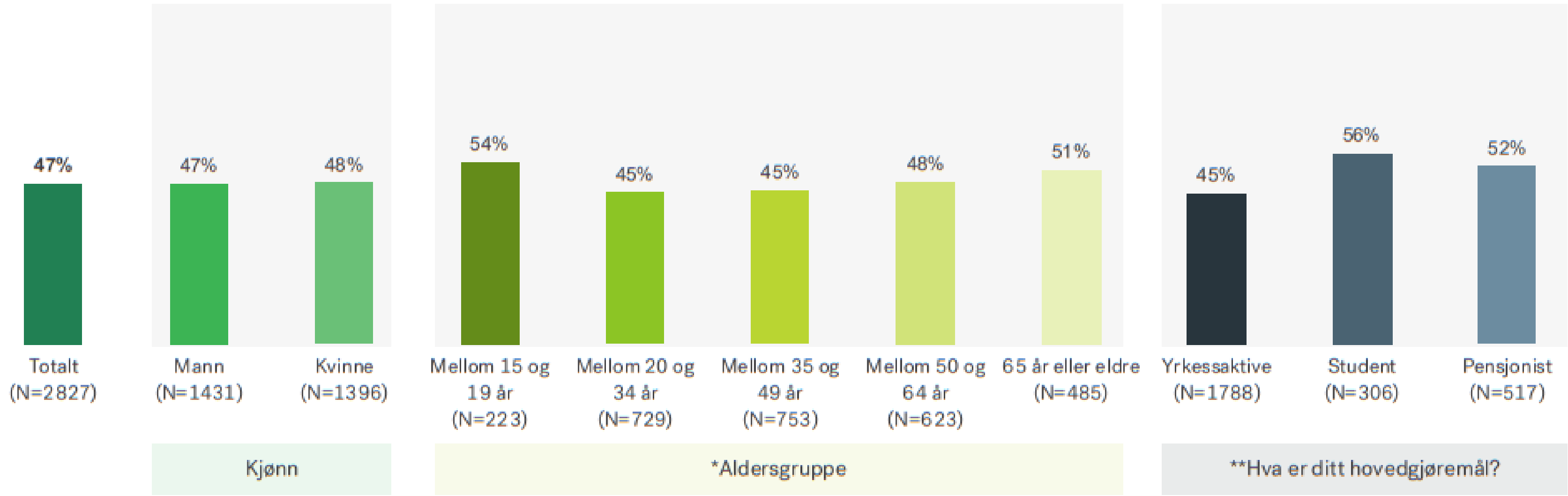
APPENDIX A: INNTRYKK AV KOLUMBUS



Kolumbus

Respondenter under 20 år er de med mest positivt inntrykk av Kolumbus.

Alt i alt, hva er ditt inntrykk av Kolumbus? / Demografi
Grafen viser andelene som svarer godt eller svært godt inntrykk.



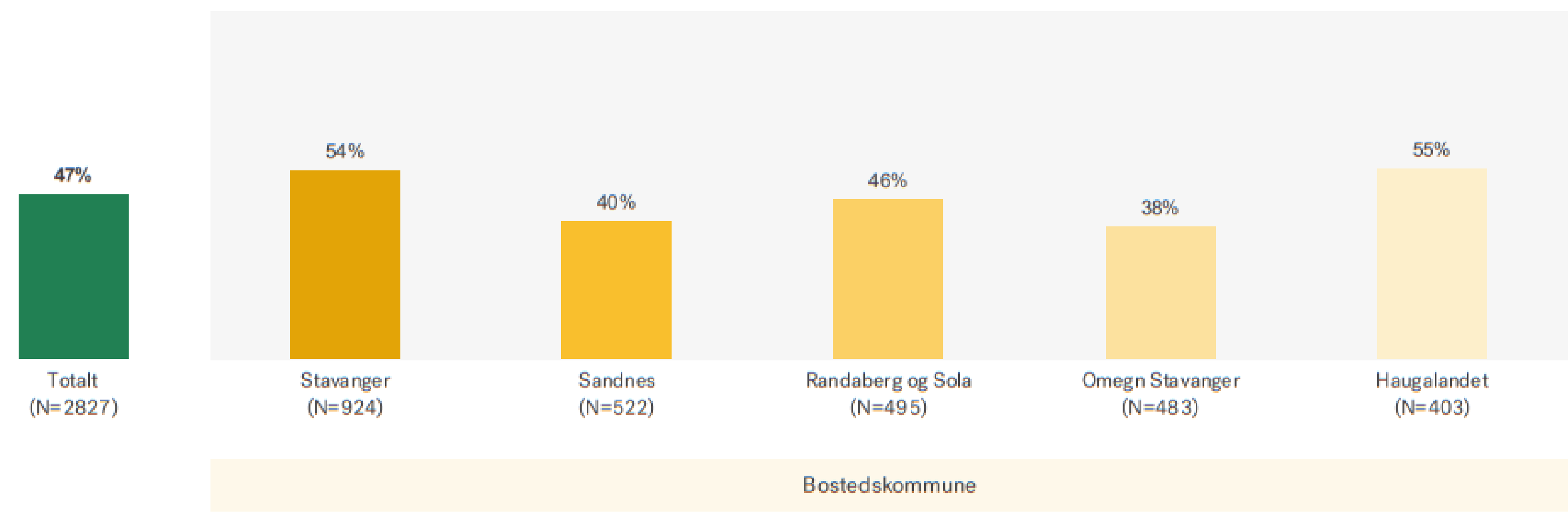
*Svaralternativet "Ønsker ikke å oppgi" på alder er ikke fremvist.
** Svaralternativene «Arbeidsløs/permittert», «Er for tiden i permisjon», «Annet», og «Vet ikke/ Ønsker ikke svare» på hovedgjøremål er ikke framvist.

Epinion

Kolumbus

Beboere på Haugalandet og Stavanger er de med mest positivt inntrykk av Kolumbus.

Alt i alt, hva er ditt inntrykk av Kolumbus? / Kommuneinndeling
Grafen viser andelene som svarer godt eller svært godt inntrykk.



72 Resultat for Kommunene «Randaberg» og «Sola» er gruppert sammen grunnet base for nedbrytning.

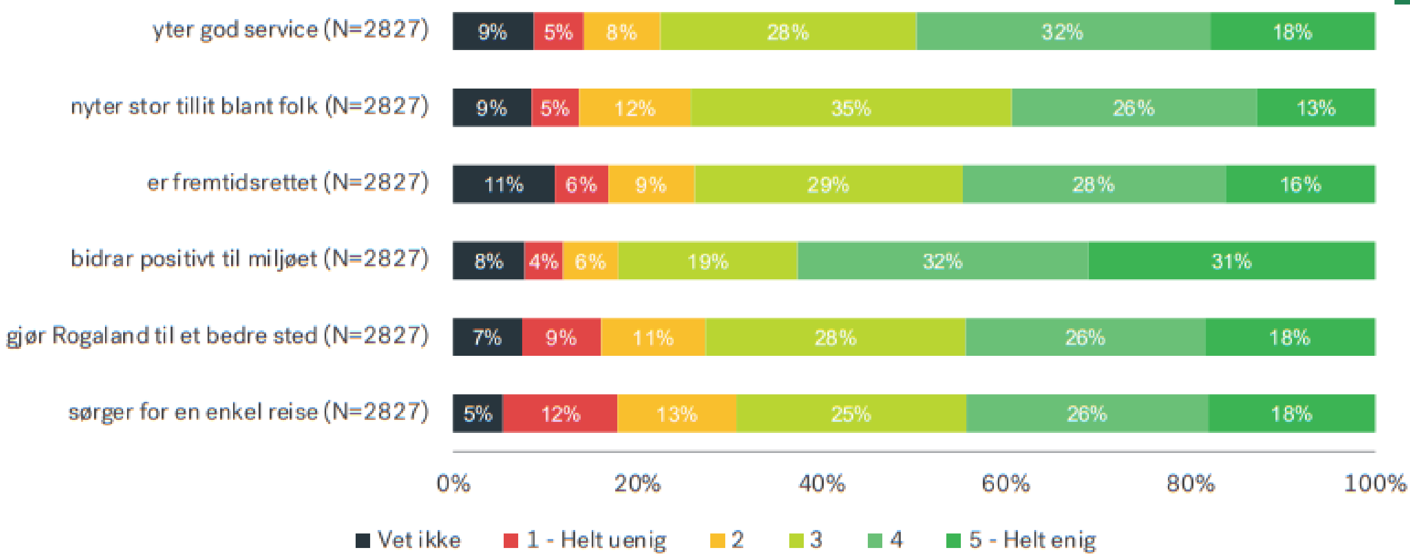
Epinion

Ulike utsagn om Kolumbus

Kolumbus

63% av respondentene er enige eller helt enige i at Kolumbus bidrar positivt til miljøet. Vi ser en gjennomgående forbedring i vurderingen sammenlignet i fjor.

Nå vil jeg be deg om å ta stilling til følgende utsagn om Kolumbus ved å svare på en skala fra 1 til 5, der 1 står for «Helt uenig" og 5 står for "Helt enig"...



Snitt 2019	Snitt 2018	Snitt 2017
3.5	3.2	3.2
3.3	3.1	3.1
3.5	3.3	3.3
3.9	3.7	3.7
3.4	3.2	3.3
3.3	3.2	--

Epinion

APPENDIX B: REPORT ON POTENTIAL OF AUTONOMOUS BUSES

Report from PRT (now Mobility Forus), given to Klepp municipality on the possibilities of route selection and potential of autonomous buses as described in chapter 3.1. The document is attached in full.

Forus PRT AS

Forusbeen 78
4033 Stavanger
(+47) 902 15 738

Trase Autonom Buss

11. Desember, 2017

Sammendrag

Rapporten bygger på en kartlegging av to traseer for å vurdere egnetheten av disse til bruk av selvkjørende buss/shuttle. Kartleggingen er gjort ved bruk av Flaate Surveyor hvor data bl.a. registreres med objektgjenkjenning og klassifisering. Analysen bygger på data innhentet på forskjellige dager, og er kategorisert i tidsintervaller. Det er i hovedsak vurdert maksimal hastighet på 25 km/t og 35 km/t på kjøretøyet.

Rapportens fokus er rettet mot det sikkerhetsmessige, det tekniske og det praktiske ved en slik implementering.

Ved begge traseene er det foreslått endringer, der betraktninger rundt kostnader også er hensyntatt og inkludert i den grad det har vært mulig.

Autonome shuttlebusser benytter i dag sensorikk med begrenset synsfelt sideveis for å detektere dynamiske/bevegelige objekter i umiddelbar nærhet, blant annet fotgjengere, syklister, dyr og andre kjøretøy. Dersom disse oppdages på god avstand vil kjøretøyet foreta en behagelig oppbremsing, avvente til banen er klar og deretter kjøre videre.

Ved behov for hurtig oppbremsing, f.eks. ved at syklister krysser veibanen i stor hastighet eller at en fotgjenger uten forvarsel går rett ut i fotgjengerfeltet, kan dette medføre en hard oppbremsing for passasjerer ombord. Dette er dessverre et vanlig fenomen i Norge, der

fotgjengere har "uskrevne lover" om vikeplikt i gangfelt. Av denne årsak har vi foreslått forskjellige mitigerende tiltak før utrulling av tjeneste, men disse kan også måtte endres som følge av erfaringer underveis.

Konklusjon

Begge traseene er svært godt egnet med tanke på sikkerhet. Det er likevel et behov for endringer på eksisterende veinett for å tilrettelegge for førerløse kjøretøy, da spesielt med tanke på lyssignaler og forkjørsvei.

Maksimal hastighet anbefales til 35 km/t for å bidra til bedre flyt i trafikken, færre forbikjøringer, og dermed økt sikkerhet. Kjøretøyet vil programmeres til saktere kjøring der hvor dette er hensiktsmessig og nødvendig. Da spesielt med tanke på fartsgrense under 35 km/t, nedbremsning ved humper, gangfelt, m.m.

Utfordringer i forbindelse med vinterføre lar seg håndtere uten at dette går på bekostning av sikkerheten.

Ved en eventuell implementering av en slik løsning vil det anses som nødvendig å ha med en operatør for kontroll, registrering av observasjoner og annen relevant informasjon, slik at man vil kunne foreta justeringer underveis, før kjøretøyet blir helt ubemannet.

Trase 1: Klepp Stasjon <-> Klepp Sentrum, v/Jærhagen

Traseet vil kunne ivareta sikkerheten i tilstrekkelig grad, og trafikkflyten vil ikke påvirkes i stor negativ grad, selv om kjøring i sone 4 i sentrum vil kunne redusere trafikkflyten.

3

Med tanke på å unngå reduksjon i trafikkflyten i sone 4 er det foreslått en alternativ rute som således anbefales i større grad. Dette alternativet har i tillegg et potensial til å være en rimeligere løsning, og vil også kunne ha andre positive effekter.

Trase 2: Klepp Sentrum, v/Jærhagen <-> Verdalen, v/enden av Boreringen

Traseet vil kunne ivareta sikkerheten i tilstrekkelig grad. Trafikkflyten vil nærmest være upåvirket i bebyggelse, mens den vil ha stor negativ påvirkning på Solavegen i sone 1.

Som følge av belastningen i sone 1 anbefales det ikke en implementering av førerløs buss/shuttle på dette traseet.

Det foreslås derimot en alternativ rute som anbefales i høyeste grad. Denne ruten erstatter sone 1, mens det resterende traseet beholdes.

Forord

Forus PRT ønsker å takke Klepp Kommune for oppdraget, som er det første av sitt slag i Norden. Dersom rapporten skulle danne grunnlag for å ta i bruk en autonom buss/shuttle vil Klepp Kommune ha en styrket posisjon dersom det er ønskelig å være først i Norden med et slikt kjøretøy i aktiv trafikk.

Innholdsfortegnelse

5

Innledning

Forus PRT har hatt i oppgave å kartlegge og analysere to mulige traseer for en autonom buss/shuttle. Oppgaven er primært av sikkerhetsmessig, teknisk og praktisk art. Det vil likevel være enkelte betraktninger rundt behovet for denne type mobilitetsløsning på traseene, samt betraktninger rundt kostnadsaspektet i forbindelse med vurdering av alternative løsninger.

En konsekvens av dagens tekniske løsninger, samt at full-autonome løsninger i aktiv trafikk ikke er implementert i Norge, er det nødvendig at valgte traseer gir kjøretøyet forkjørsrett. Betraktninger, vurderinger og anbefalinger for nødvendige endringer fra dagens vegstrekning vil derfor være en naturlig del av rapporten.

For å unngå de største utfordringene i de aktuelle traseene har vi valgt å foreslå noen alternative varianter. Ved alternativene er det lagt spesielt vekt på følgende:

- Unngå vesentlig reduksjon av dagens trafikkflyt
- Sikkerhet
- Unngå "melkeruter"; brukerne er opptatt av å transporteres på en smidig måte fra A til B

Kostnadsbildet ved den enkelte løsning er også vektlagt og kommentert, men kan ikke sies å kunne være "lagt spesielt vekt på" da dette vil kreve en betydelig økning i omfanget av utredningen.

Kartleggingen av traseene utføres ved bruk av Flaate Surveyor, hvor bl.a. avansert system for objektgjenkjenning og klassifisering bidrar til kartleggingen. Forus PRT er den eneste aktøren i Norden som siden januar 2017 har gjennomført omfattende testing, av førerløs buss/shuttle, og har vært involvert i forbindelse med input til Samferdselsdepartementet med tanke på utarbeidelse av nytt lovverk. Forus PRT er i så måte i en særstilling med tanke på kartlegging, analysering og evaluering av traseene.

Stortinget behandlet "Lov om utprøving av selvkjørende kjøretøy" 28.11.2017 der innstillingen fra transport- og kommunikasjonskomiteen ble enstemmig vedtatt. Loven og tilhørende forskrift skal blant annet sikre at slik utprøving skjer gradvis, i takt med teknologiutviklingen og innenfor rammer som ivaretar trafikksikkerhet og personvern. Formålet er å avdekke hvilke effekter selvkjørende kjøretøy kan ha for trafikksikkerhet, effektivitet i trafikkavviklingen, mobilitet og miljø.

Traseene er som følger:

- **Klepp Stasjon <-> Klepp Sentrum, v/Jærhagen:**

Traseet er på 3.4 km hvor det i dag er 40, 50 & 60 sone, rundkjøringer, forkjørsvei og ikke forkjørsvei.

7

- **Klepp Sentrum, v/Jærhagen <-> Verdalen, v/enden av Boreringen:**

Traseet er på 3.2 km hvor det i dag er 30, 40, 50 & 60 sone, rundkjøringer, forkjørsvei og ikke forkjørsvei.

Bakgrunn

Teknologien har nå kommet såpass langt at førerassistentsystemer, såkalt ADAS (Advanced Driver Assistance Systems), i stadig økende grad implementeres i ordinære kjøretøy. ADAS er i stor grad å betrakte som systemer som på sikt vil utgjøre teknologien i et full-autonomt kjøretøy.

I tillegg til at man er i en teknologisk tidligfase innen autonomi, er det store spørsmål til den praktiske konsekvensen av trafikkbildet der autonome kjøretøy vil ferdes. Mange av disse spørsmålene vil være vanskelige å besvare før man har benyttet kjøretøyet i aktive miljøer.

På grunn av usikkerheten i forbindelse med implementering av ny teknologi vil det være absolutt nødvendig med en grundig evaluering av hvert enkelt trase som vurderes. I evalueringen av implementering av autonome kjøretøy i Boston, USA, nevnes;

> *"Every city will need to perform its own testing to identify the form (or forms) of Autonomous Vehicle transportation best suited to its specific circumstances and transportation challenges and goals"*

* Making autonomous vehicles a reality. Lessons from Boston and beyond. Boston USA: The Boston Consulting Group (2017)

Ved å benytte spesialkjøretøy for denne type kartlegging (ref.: http://bussmagasinet.no/?p=8145) vil traseene kartlegges grundig for å skaffe til veie et best mulig datagrunnlag for vurderingen. Se forøvrig www.forusprt.com/surveyor.

Selv om autonome kjøretøy ikke er i aktiv trafikk i Norge finnes disse i flere byer i Europa, Australia, Asia og USA. Byer som Bordeaux, Lyon, Sion, Doha og Perth har førerløs transport i offentlige gater, og i et betydelig antall steder vurderes tilsvarende løsning.

Arbeidet som er gjort

Ifølge Nederlandske forskere (Vissers m.fl. 2016) har utviklingen av teknologien for autonome kjøretøy i hovedsak fokusert på å oppdage og gjenkjenne fotgjengere og syklister. Selv om teknologien har kommet langt er det fortsatt en del utfordringer med tanke på pålitelighet i spesielle værsituasjoner, men er nødvendig for sikker interaksjon mellom det førerløse kjøretøyet og fotgjengere/syklister (Summers 2017; Zhou 2017). For å ivareta kravet om sikkerhet er det derfor gjennomført kartlegging som tar utgangspunkt i en maksfart på henholdsvis 25 km/t og 35 km/t i begge traseene.

For å ha et best mulig statistisk grunnlag er det utført totalt 94 gjennomkjøringer, i løpet av flere ukedager. Da trafikkbildet for kjørende, gående og syklende, varierer sterkt er det nødvendig å skaffe et bilde av bevegelsesmønsteret i løpet av dagen. Observasjonene er derfor kartlagt i fire tidsintervaller;

07:00 - 08:30 **08:30 - 14:30** **14:30 - 17:00** **17:00 ->**

I datasettet er det skilt mellom observasjoner og forbikjøringer;

- Tungtransport (Observasjon & Forbikjøring)
- Buss (Observasjon & Forbikjøring)
- Personbiler & andre kjøretøy (Observasjon & Forbikjøring)
- Gående (Observasjon)
- Syklende (Observasjon)

Observasjoner for kjøretøy er tilfeller der det ville vært en interaksjon mellom kjøretøyet og førerløs buss/shuttle, utenom forbikjøring som registreres separat. Dvs. at et kjøretøy i motgående retning ikke registreres som en observasjon, med mindre kjøretøyet ville krevd en aksjon eller skapt en hendelse av betydning.

Ved gående er formålet å kartlegge de som er en del av trafikkbildet, som et førerløst kjøretøy må hensynta, men også for å ha et grunnlag for å si noe om behovet for denne type mobilitetsløsning. Gående som går tur med hund er ekskludert fra datasettet, med mindre det ville krevd en aksjon eller skapt en hendelse av betydning.

Hvert trase har videre vært delt inn i fire soner. Årsaken til dette er at hver sone anses å være vesentlig forskjellig fra resten av traseet, og derfor har behov for et særskilt fokus og vurdering.

Trase 1: Klepp Stasjon <-> Klepp Sentrum, v/Jærhagen

1. Sone

Fra stasjonen på Klepp Stasjon og opp til og med første rundkjøring. Veien er 40-sone, og ikke forkjørsvei.

2. Sone

Etter første rundkjøring frem til 50-sone ved bebyggelse. Veien er 50-sone ca 200 meter, og resten 60-sone. Forkjørsvei.

3. Sone

50-sone mot sentrum. Forkjørsvei.

4. Sone

Fra sentrum til Jærhagen. Stort sett 40-sone. Forkjørsvei.

13

Trase 2: Klepp Sentrum, v/Jærhagen <-> Verdalen, v/enden av Boreringen

1. Sone

Fra Jærhagen, over RV44, til Verdalsvegen. 40- og 60-sone. I hovedsak forkjørsvei.

2. Sone

40-sone Verdalsvegen. Ikke forkjørsvei.

3. Sone

30-Sone. Ikke forkjørsvei.

4. Sone

50-sone. Ikke forkjørsvei.

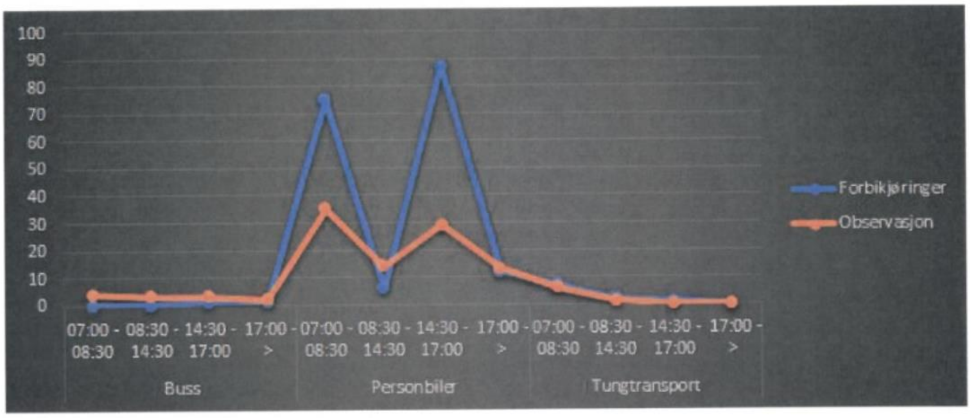
Resultater

Trase 1: Klepp Stasjon <-> Klepp Sentrum, v/Jærhagen

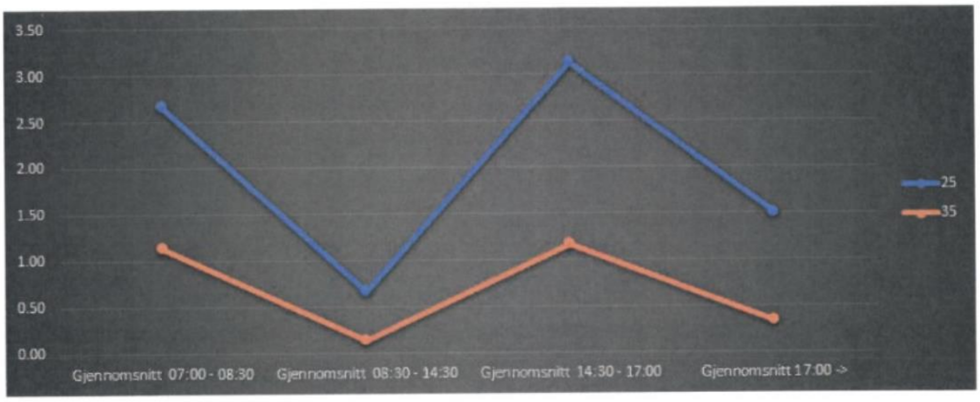
Det er generelt en del trafikk, både av kjøretøy og myke trafikanter, og da spesielt i tidsrommet 07:00 - 08:30 og 14:30 - 17:00. Selv med maksimal fart på 25 km/t er den trafikale avviklingen tilfredsstillende, mens en økning til maksimal fart på 35 km/t bidrar til at kjøretøyet vil være mindre belastende i trafikken. Samtlige registreringer av forventede forbikjøringer av et førerløst kjøretøy finner sted i sone 2 i traseet, hvor fartsgrensen er 60 og oversikten er god. Da trafikken er størst når trafikantene er på vei til/fra arbeid er enkelte sjåfører travle, og enkelte forbikjøringer vil kunne bli betraktet som unødvendige.

16

Grafen viser antall observasjoner og forbikjøringer fordelt på kjøretøy og tidsintervall. Her fremkommer totalt antall uavhengig av hastighet:

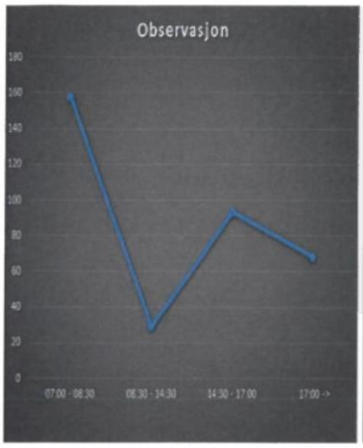


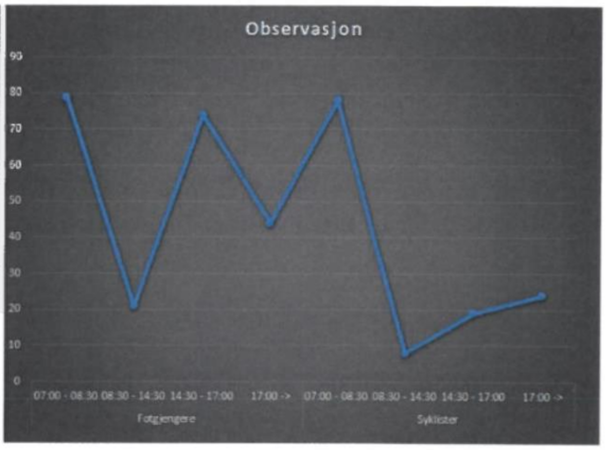
Grafen viser gjennomsnitt antall forbikjøringer på 25 km/t og 35 km/t. En økning i maksimal hastighet fra 25 km/t til 35 km/t reduserer forbikjøringer med mellom 58% og 81%, noe som må sies å være betydelig:



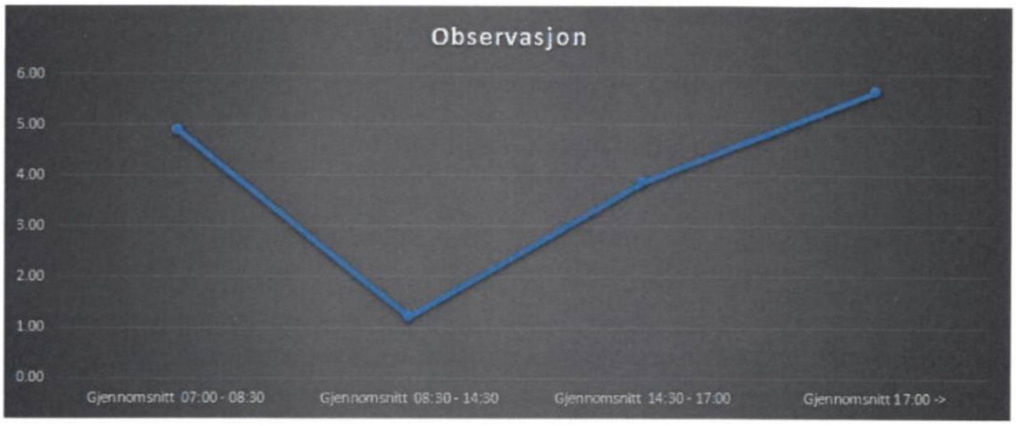
17

Av myke trafikanter er det en betydelig trafikk jevnt over hele dagen, men med spesielt høyt antall tidlig (ref. graf 1 under, mens graf 2 viser fordelingen mellom syklende og gående).



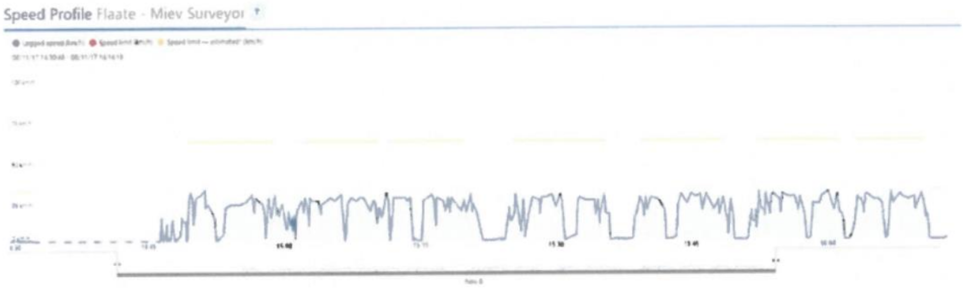


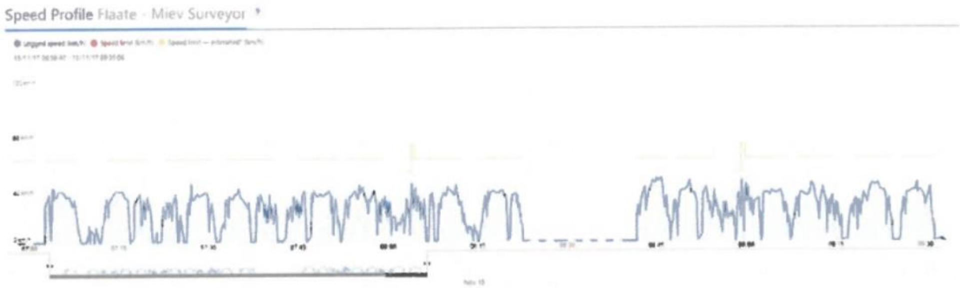
Gjennomsnittet av myke trafikanter per gjennomkjøring tyder på at en tur sjeldent vil foregå uten passasjerer:



18

Grafene under viser fartsmønsteret i ruten. Første graf viser ved maksimal hastighet på 25 km/t, mens den nederste viser 35 km/t. Her får man et innblikk i hvor ofte i løpet av ruten man er under maksimal hastighet, noe som indikerer at kjøretøyet dermed ikke vil kunne betraktes som et hinder, men følger trafikkflyten som er på strekningen.





Vi har i tillegg valgt å foreta tellinger av kjøretøy parkert på togstasjonen på tilfeldige dager, og tilfeldig klokkeslett. Hensikten er å få et innblikk i hvor mange kollektivbrukere der er, men som ikke finner dagens transport fra hjemmet til togstasjonen tilfredsstillende. Disse vil naturligvis være potensielle brukere for en førerløs buss/shuttle.

Kl 07:13	57 kjøretøy
Kl 07:30	50 kjøretøy
Kl 08:16	65 kjøretøy
Kl 09:35	81 kjøretøy
Kl 14:45	77 kjøretøy
Kl 15:15	70 kjøretøy
Kl 18:40	12 kjøretøy
Kl 18:45	25 kjøretøy

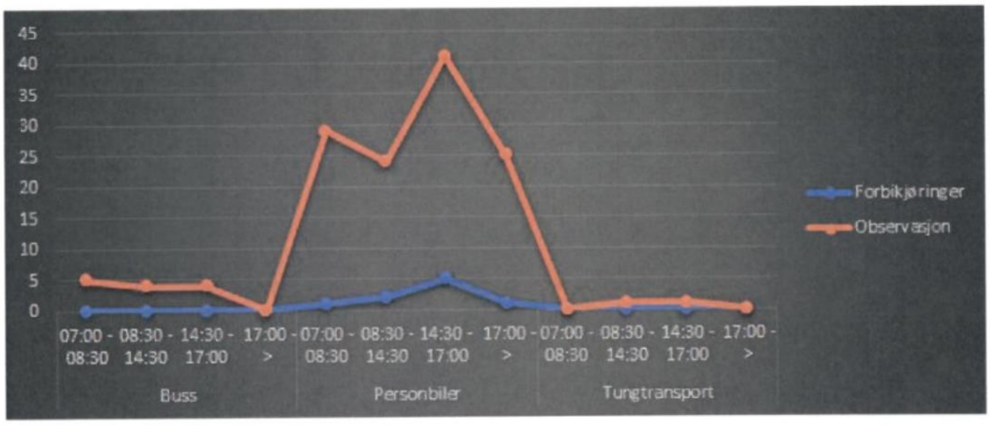
I denne forbindelse valgte vi å gjennomføre en del spørringer av togpassasjerene for videre kartlegging. Spørringene fant sted på tre avganger/ankomster der 63 personer besvarte.

Verdalen	38	60%
Nær Klepp Stasjon	10	16%
Grensen mot Bryne	4	6%
Klepp Sentrum	11	18%

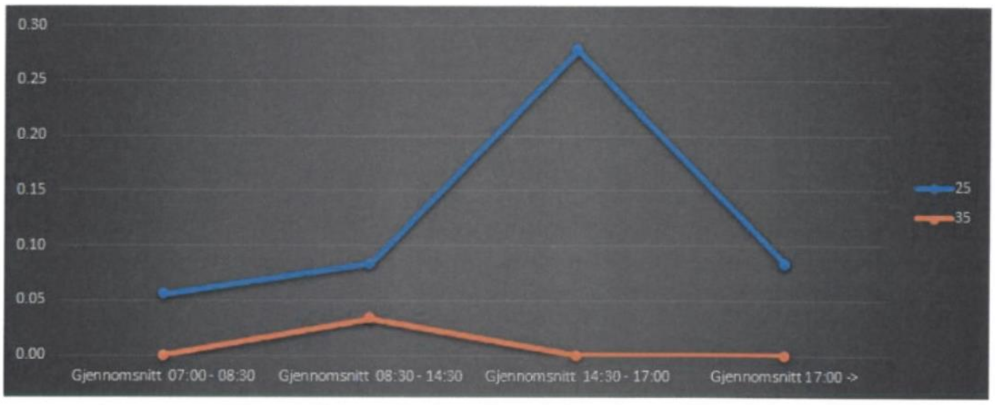
Trase 2: Klepp Sentrum, v/Jærhagen <-> Verdalen, v/enden av Boreringen

Det er generelt en del trafikk, både av kjøretøy og myke trafikanter. Tidsrommet 07:00 - 08:30 har flest myke trafikanter, mens tidsrommet 07:00 - 08:30 og 14:30 - 17:00 har flest kjøretøy. Selv med maksimal fart på 25 km/t er den trafikale avviklingen svært god, med unntak av sone 2 som har 60-sone og dobbel sperrelinje, og svært trafikkert rundkjøring. Resten av traseet har svært få observasjoner som vil medføre ulempe med et førerløst kjøretøy. Forbikjøringer forekommer sjeldent, men da i sone 2 hvor fartsgrensen er 40 og oversikten er god. Kun en forbikjøring forekom ved maksimal hastighet på 35 km/t.

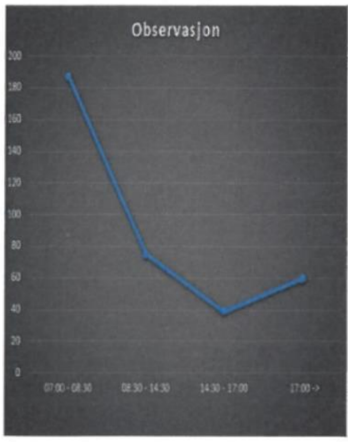
Grafen viser antall observasjoner og forbikjøringer fordelt på kjøretøy og tidsintervall. Her fremkommer totalt antall uavhengig av hastighet:

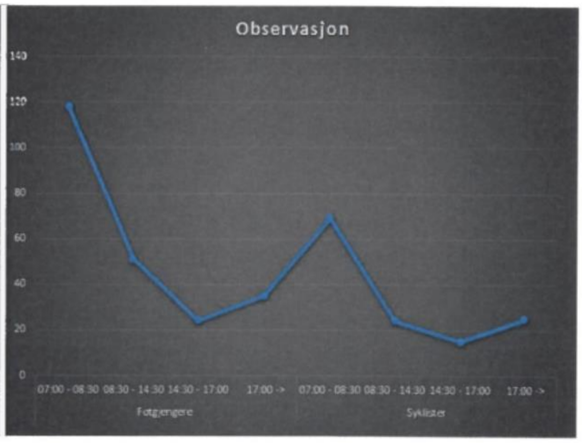


Grafen viser gjennomsnitt antall forbikjøringer på 25 km/t og 35 km/t. Denne viser en stor prosentvis forskjell, og tilnærmet fravær av forbikjøringer ved maksimal hastighet på 35 km/t.:

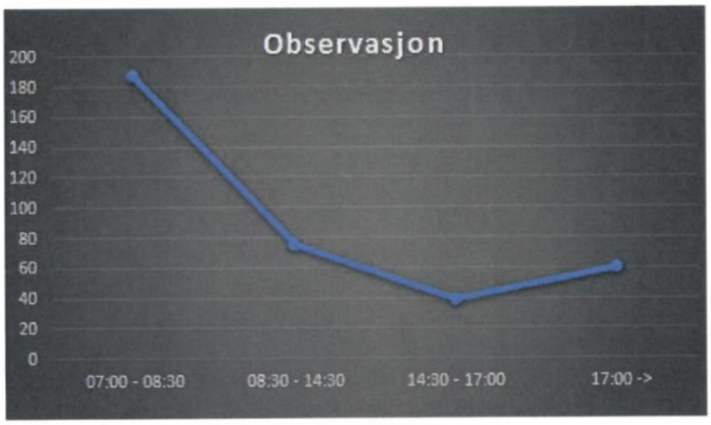


Av myke trafikanter er det en betydelig trafikk jevnt over hele dagen, men med spesielt høyt antall tidlig (ref. graf 1 under, mens graf 2 viser fordelingen mellom syklende og gående).

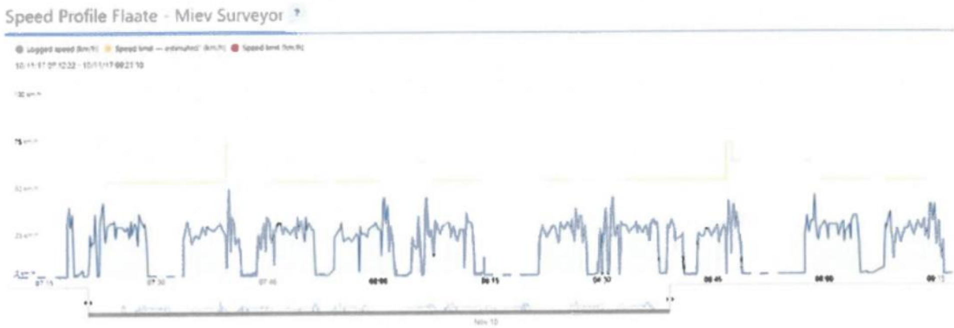


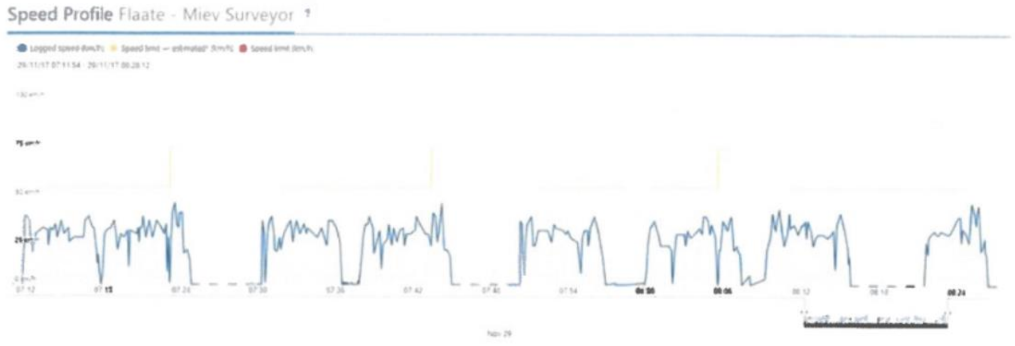


Gjennomsnittet av myke trafikanter per gjennomkjøring tyder på at en tur sjeldent vil foregå uten passasjerer:



Grafene under viser fartsmønsteret i ruten. Første graf viser ved maksimal hastighet på 25 km/t, mens den nederste viser 35 km/t. Her får man et innblikk i hvor ofte i løpet av ruten man er under maksimal hastighet, noe som indikerer at kjøretøyet dermed ikke vil kunne betraktes som et hinder, men følger trafikkflyten som er på strekningen.





Drøfting

Generelt har begge traseene fordeler med en relativt rett strekning. Dette bidrar til at man transporteres smidig til sin destinasjon. I tillegg er traseene svært komplementære ved at man vil kunne transporteres mellom Verdalen og Klepp Stasjon, samtidig som sentrum blir knutepunktet. Basert på rutebussenes frekvens, observasjoner av myke trafikanter og parkerte kjøretøy ved Klepp Stasjon, oppfattes det som at en førerløs buss/shuttle vil kunne tilfredsstille et åpenbart mobilitetsbehov langs disse traseene. Felles for begge er likevel noen utfordringer, spesielt med tanke på behovet for forkjørsrett, at enkelte deler av traseene har stor trafikk, og at man må påse at parkering langs veien ikke er til hinder for kjøretøyet.

En førerløs buss/shuttle er tenkt som et supplement til busser i rute, og ikke en substitutt. Dette vil kunne bidra til at rutebusser bruker kortere tid på sine lengre ruter ved at tiden som brukes der hvor en førerløs buss/shuttle opererer blir kortere. På sikt vil også rutebussenes traseer kunne tilpasses for å optimalisere mobilitetsbehovet, og dermed transportere brukerne raskere fra/til destinasjonen, ut av sentrumsområdet. Ordinære bemannede bussruters kostnader er i stor grad knyttet til lønnskostnader og drivstofforbruk, og bidrar derfor i stor grad til en begrensning i antall avganger. Med en førerløs løsning på et el-drevet kjøretøy er denne kostnaden begrenset i stor grad. Når man først har kjøretøyet på plass vil man derfor kunne utnytte dette ved at kjøretøyet ferdes også på mindre trafikkerte tidspunkt, og gir befolkningen en økt fleksibilitet.

Dersom en mobilitetsløsning ved bruk av førerløs buss/shuttle implementeres i de nevnte traseene vil dette kunne ha en positiv innvirkning på det lokale næringslivet, samt andre tilbud i området. Jærhagen vil eksempelvis kunne få en økning av kunder pga økt ferdsel, mens idrettsanlegg og skøytebanen vil få en lettere adkomst for kommunens befolkning.

Planlegging av vegarbeid, eller andre tiltak i veibanen må planlegges i annen grad enn hva som er tilfellet i dag. Ved bruk av dagens teknologi er det begrensninger i forhold til å få kjøretøyet til å kjøre rundt hindringer. Utfordringen vil trolig likevel kunne la seg løse ved at f.eks. vegarbeid planlegges, med dialog med operatørselskapet som håndterer bussen/shuttelen. Parkering i kjøretøyets vegbane må også hindres av samme årsak.

Som nevnt vil førerløse busser/shuttler kreve forkjørsrett. Dette vil også anbefales for gangfelt, enten ved bruk av lyssignaler eller skilting. Kjøretøyet vil uansett sakke ned farten, og stanse dersom noe beveger seg ut i veibanen, slik at den likevel kan ferdes uten et slikt lyssignal. Det er også verd å merke seg at det finnes forskjellige produsenter, med forskjellige modeller, med forskjellig sensorikk. Enkelte kjøretøy vil derfor være mer egnet enn andre i traseer med gangfelt.

En praktisk utfordring på vinterstid vil kunne være kjøretøyets håndtering av snø, is og brøytekanter. Felles for de forskjellige modellene av førerløse busser/shuttler, er at sensorikken i hovedsak er laserstyrt. Ved kraftig snøfall kan dette føre til rykkete og sakte kjøring. Dersom det legger seg brøytekanter innen den definerte rekkevidden vil kjøretøyet stanse og ikke fortsette før hindringen fjernes, eller kjøretøyet styres manuelt. Når det er glatt veibane vil hastigheten kunne omprogrammeres til sakte kjøring. En generell betraktning av begge traseene er at utformingen av disse er svært gunstige med tanke på glatt føre. Dette baserer seg på generell lav hastighet, lav helning og få svinger.

Videre bør det vurderes å etablere en eller flere værstasjoner fra Statens Vegvesen langs traseet for trafikkplanlegging og drift. Se forøvrig https://www.vegvesen.no/trafikkbeta for mer informasjon.

Kjøretøyet vil forhåndsprogrammeres med tanke på hastighet, slik at farten tilpasses fartsgrensen (eks. om man har 35 km/t maksimal hastighet på kjøretøyet og kjører i 30-sone), fartshumper, eller områder hvor kjøretøyets sensorikk har hindringer (levegger, gjerder, m.m.).

Ved vurdering av kjøretøyets maksimale hastighet er det i hovedsak tre aspekter som det fokuseres på:

- Utvendig sikkerhet
- Innvendig sikkerhet
- Trafikal avvikling

Ved "utvendig sikkerhet" vil traseet vurderes med tanke på områder hvor forsvarlig ferdsel tilsier lavere hastighet enn fartsgrensen.

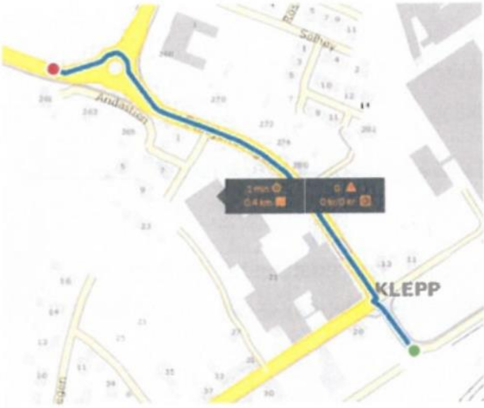
Ved "Innvendig sikkerhet" vil risiko for passasjerer ved en evt. nødstopp tas i betraktning. På grunn av manglende datagrunnlag på passasjer-risiko i slike kjøretøy er det viktig at hastigheten begrenses.

Ved "Trafikal avvikling" vil kjøretøyets påvirkning av trafikkbildet legges til grunn. Her er det et element av trafikksikkerhet og et element av hindring av annen trafikk som vurderes. Med tanke på trafikksikkerhet ser vi at en maksimal hastighet på 25 km/t vil generere flere forbikjøringer, enn i 35 km/t. Selv om skadeomfanget vil være større i 35 km/t generelt sett vil likevel risikoen i flere tilfeller betraktes som høyere dersom man kjører i 25 km/t. Med tanke på hindring av annen trafikk er det naturlig å gjøre vurderinger av omfanget, for å kunne overveie kost/nytte.

Trase 1: Klepp Stasjon <-> Klepp Sentrum, v/Jærhagen

Det generelle inntrykket er at traseet er svært godt egnet for en førerløs buss/shuttle, i tillegg til at behovet absolutt er til stede. En eventuell oppstart vil trolig medføre at denne tas i bruk umiddelbart, da det stort sett i løpet av hele dagen er fotgjengere og syklister på gang- og sykkelvei.

Sone 1



Denne delen av veien er ikke forkjørsvei, og må derfor gjøres om. Alternativet er å sette opp lyssignaler som automatisk gir klarsignal til kjøretøyet. Et annet alternativ er å flytte enden av traseet lenger opp til der hvor man har forkjørsvei. Det sistnevnte alternativet vil ikke anbefales da dette trolig strider mot hensikten, og øke brukerterskelen.

På grunn av lav hastighet er det forventet at hverken maksimal hastighet på 25 km/t eller 35 km/t vil være til hinder for trafikken. Likevel ser vi at en maksimal hastighet på 35 km/t ikke vil utgjøre en vesentlig risiko, da programmert hastighet vil tilpasses med tanke på kryss, gangfelt, m.m.

Sone 2

Hele veien er forkjørsveg. Det er på dette strekket all forbikjøring i hovedsak forekommer. Selve traseet er svært godt egnet, og maksimal hastighet på 35 km/t bør benyttes. Årsaken er at dette vil gi en mer smidig trafikkavvikling, og samtidig redusere forbikjøringer.

Sone 3

Denne delen er forkjørsvei med 50-sone, og har flere kryss. En førerløs buss/shuttle vil likevel ikke være til særlig hinder i trafikken, og vil ikke ha store utfordringer med traseet.

Sone 4

Stort sett 40-sone og forkjørsvei frem til avkjørsel til Jærhagen. Rundkjøringene vil likevel trolig måtte utrustes med lyssignal. Selv om kjøretøyet ikke vil ha problemer med veien er likevel trafikkbildet såpass komplisert at den ordinære trafikkavviklingen vil kunne hindres i større grad enn ved resten av traseet. Det er åpenbart at denne strekningen er hovedutfordringen for hele traseet, men distansen er likevel ikke betydelig.

Et alternativ er å kutte ut hele denne sonen, men da vil fordelen ved å knytte begge traseene sammen forsvinne. Ut i fra antall fotgjengere og syklister vil det likevel være et betydelig antall brukere. Rapporten tar ikke stilling til dette da det vil være kommunens kost-/nytte vurdering som må legges til grunn.

Vi ønsker å legge fram et alternativ til sone 4, som vi mener vil ha flere fordeler. Selve distansen er helt identisk. Det er vanskelig å estimere kostnadene på de to variantene uten å gjøre en utvidet analyse, men alternativet har potensiale til å bli rimeligere og samtidig dekke behovet i større grad. Fordelene er bl.a.:

- Fjerner i stor grad den førerløse bussen/shuttelen fra den mest trafikkerte delen av ruten
- Lettere adkomst/stoppested ved boligblokker/høyblokker (i bunnen av bildet)
- Bedre tilknytning til idrettsanlegg både fra Klepp Stasjon og Verdalen
- Økt attraktivitet for næringsvirksomhet ved Idrettsvegen, og området rundt
- Sykehjemmet i Olav Hålandsveg 8 knyttes tettere mot løsningen

Innenfor prosjektets rammer har det ikke vært mulig å gå dypere i det fulle potensialet til en tilbringertjeneste Verdalen – Klepp sentrum/Jærhagen – Klepp stasjon.
Det finnes imidlertid datamateriale hos samarbeidspartnere av Forus PRT som kan tilgjengeliggjøres ved behov som vil gi betydelig større innsikt i

- hvilke bedrifter innbyggere i Klepp pendler til
- på hvilke tidspunkt pendlingen skjer
- hvilken innpendling det er fra andre kommuner til bedrifter i Klepp

På denne måten er det mulig sette opp en oversikt over det totale pendlingsbildet for kommunen ned på bedriftsnivå, hvor stor del av pendlingen som ikke kan flyttes over på offentlige kommunikasjonsmidler på grunn av levering i barnehage, bruk av servicebiler mv, ineffektivitet i overgang mellom transportmidler (for kort reisevei mv). Når dette er avklart vil man sitte igjen med et restpotensiale for overgang til offentlige kommunikasjonsmidler som vil være det reelle taket for hva som er mulig å få til. Gjennom kontakt med den enkelte bedrift er det da mulig å tilrettelegge for målrettede tiltak for å få innbyggere i Klepp kommune til i større grad å ta i bruk offentlige kommunikasjonsmidler.

Siden datamaterialet allerede finnes, så vil et eventuelt prosjekt bestå i å analysere materialet, noe som vil ta maksimalt 2 personer i 3 dager. Deretter vil det være mulig å presentere resultatet for Klepp kommune, og eventuelt avtale ytterligere avklaringer dersom det skulle være behov for det. Forus PRT mener at en slik innsikt i innbyggernes bevegelser vil gi et betydelig bedre beslutningsgrunnlag, og vil gi Forus PRT viktig informasjon om bo- og arbeidssted for de endelige målgruppene for en tilbringertjeneste.

Trase 2: Klepp Sentrum, v/Jærhagen <-> Verdalen, v/enden av Boreringen

Det generelle inntrykket er at traseet er svært godt egnet for en førerløs buss/shuttle, med ett betydelig unntak, i tillegg til at behovet absolutt er til stede. Årsaken til den spesielle egnetheten er at traseet stort sett er oversiktlig med tanke på kjøretøyets sensorikk, og veien har god bredde. Store deler av traseet er uten forkjørsvei, noe som må gjøres om. En eventuell oppstart vil trolig medføre at denne tas i bruk umiddelbart, da det stort sett i løpet av hele dagen er fotgjengere og syklister på gang- og sykkelsti. Unntaket til god egnethet er ferdsel på Solavegen, noe som utdypes i punktet under vurdering av sone 1.

Sone 1

Denne delen av veien har forkjørsvei med unntak av området fra Solavegen mot Jærhagen, og må derfor gjøres om eller få lyssignal. Denne delen av traseet inneholder fire rundkjøringer, som må få lyssignaler. Strekket fra rundkjøring ved RV44 mot Verdalsvegen har 60-sone med dobbel sperrelinje. Det vurderes slik at denne delen av traseet er svært uegnet til en førerløs buss/shuttle. Årsaken er ikke sikkerhetsrelatert, men betydelig hindring av sterkt trafikkert vei.

Sone 2

Med unntak av manglende forkjørsvei er denne sonen svært godt egnet. Fartsgrensen er såpass lav at kjøretøyet ikke medfører vesentlig hindring av annen trafikk, samtidig som oversiktligheten for sensorikken er god.

33

Sone 3

Som ved sone 2 er også denne svært godt egnet. Fartsgrensen er 30 km/t, slik at en førerløs buss/shuttle ikke vil være til hinder for annen trafikk som følge av hastigheten. Like ved skolen har veien en innsnevring. Denne må tilrettelegges for å håndtere kjøretøy i rute. Alternativt vil man kunne legge om ruten slik som bildet under:

Sone 4

Denne delen av traseet er også svært godt egnet. Fartsgrensen er 50 km/t, og veien er bred og lite trafikkert. Veien er ikke forkjørsvei.

Vi ønsker også her å legge fram et alternativ til sone 1, som vi mener vil ha flere fordeler. Selve distansen er 200 meter lengre. Det er vanskelig å estimere kostnadene på de to variantene uten en grundig analyse, men alternativet har potensiale til å bli en god del rimeligere, og samtidig dekke behovet i større grad. Fordelene er bl.a.:

- Fjerner den førerløse bussen/shuttelen fra den mest trafikkerte delen av ruten
- Øker nærheten til boligområdet i nordøst, og vil dermed kunne øke antall bruker

Ulemper:

- Traseet går i all hovedsak på gang- og sykkelvei

Her er det usikkerhet rundt hva som vil kreves av fysiske endringer. Det er mulig veien må gjøres noe bredere, men flere av eksisterende førerløse busser/shuttler er smale, og vil muligens kunne få plass til at barnevogner og rullestoler vil kunne passere. Det er også usikkert hva myndighetene vil kunne tillate av slik ferdsel uten å utbedre og omdefinere veien. Basert på dagens gang- og sykkelvei ville kjøretøyet måtte holde en svært lav hastighet i dette området.

Kostnadsaspektet

Som nevnt er det vanskelig å si noe om kostnadene for å tilrettelegge traseene for en førerløs buss/shuttle uten å gjennomføre en grundig analyse. I og med at man vil kunne være blant de aller første, om ikke den første, i Norge til å ta i bruk en førerløs buss/shuttle i aktiv trafikk, er det store muligheter for bidrag til å dekke en del av kostnadene. Eksempelvis er Transportøkonomisk Institutt svært interessert i å få tilgang på data til analyse av effekten av et slikt kjøretøy i aktiv trafikk. Dette vil kunne være et insentiv for særskilte midler til et slikt prosjekt. Det er i tillegg stor sannsynlighet for at Jærhagen vil kunne øke antall besøkende, og dermed betrakte et slikt tiltak som svært ønskelig. Det er derfor ikke utenkelig at private aktører som Jærhagen eller andre vil kunne bidra med midler, i tillegg til offentlige midler som bl.a. ENOVA med tanke på CO2-reduserende tiltak.