AUTOMATED SHUTTLE SERVICES IN PUBLIC TRANSPORT. LESSONS LEARNED FROM THE SMART FEEDER RESEARCH PROJECT IN NORWAY.

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1. BACKGROUND

Automated mobility services hold a potential to change the way transport is performed, giving rise to previously unknown possibilities, but also new challenges as well. The technology push is significant, as the automotive industry and technology providers are in head of a rapid technology development, while the transport authorities are captivated by promising benefits on improved safety and efficiency. How do we make sure the technology is applied in such a way that we move towards a more sustainable transport future? Smart mobility services need to be developed as part of a safe, efficient, and user-friendly public transport system. Furthermore, potential barriers in terms of technical, legal, and societal challenges need to be identified and overcome. Hence, policy makers are in urgent need of knowledge on how technological innovations and automated mobility services should be realised to obtain beneficial impacts for users and society.

In recent years, automated shuttle buses at SAE level 4 (SAE J3016, 2016) have been introduced as commercial products, ready for large scale piloting in real life environments. In Norway, the legal framework for testing of automated vehicles on public roads became effective in January 2018. Since then, extensive pilot activities have been conducted, leading to Norway being ranked among the top three countries in the world in terms of being prepared for the future deployment of autonomous vehicles (KPMG, 2019; 2020).

The SmartFeeder research project (2017-2020) has studied the introduction of automated shuttle buses in Norway. The purpose is to use the early pilot experiences to build knowledge on how automated mobility services should be implemented in the future transport system.

2. THE SMART FEEDER RESEARCH PROJECT

The SmartFeeder research project was initiated by the National Railway Directorate, in order to gain knowledge on how automated first- and last mile services can improve the railway and other modes of public transport, and thereby contribute to a green shift in passenger transport. The aim of the project is twofold; 1) to enhance public mobility solutions for the future transport system, and 2) to build a comprehensive knowledge basis for future development and policies on automated transport in collaboration between public authorities, private actors and scientists.
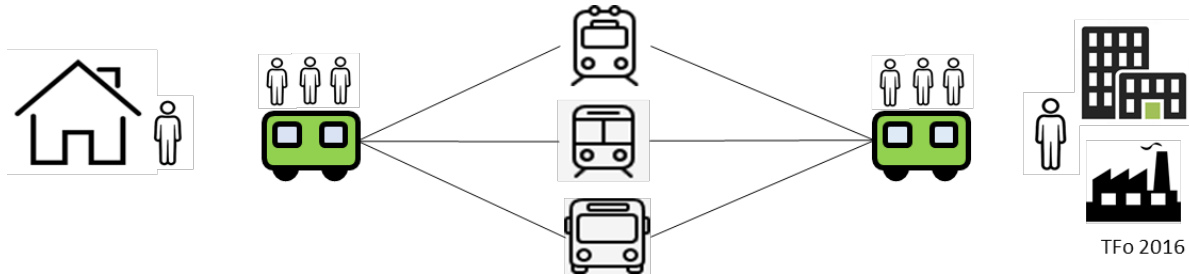
Figure 1: The SmartFeeder concept of first and last mile automated shuttle services

SmartFeeder is an independent research project funded by the Norwegian Research Council. The project collaborates with five progressing pilots, all running in mixed traffic on public roads.

2.1 The Forus Pilot

The Forus Pilot is located in an industrial area in the western part of Norway. The test site environment is exposed to quite harsh weather conditions, with a considerable amount of rain, wind, and fog, although there is relatively little snow during winter. An automated shuttle bus from EasyMile (EZ10, 1. Gen) was tested on a closed test track for 12 months with regards to technology reliability and traffic safety issues, before pilot activities in mixed traffic on public roads were launched in June 2018. In the first test phase, a total of 1700 hours in driverless mode were performed, with targeted testing of traffic safety performance in interaction between the automated shuttle bus and pedestrians, bicyclists, and other vehicles. In the next phase, the shuttle bus was set out to connect employees to the ordinary public transport system as a first and last mile service. The test site involves a 1,2 km long public road section with a rather high complexity of mixed traffic and junctions. A total of 6.000 passengers and 5.000 km were covered during a six months test period. Effort was put in user involvement and marketing, including the assessment of different aspects of user acceptance.

2.2 The Fornebu Pilot

The Fornebu Pilot is located in a residential area in the city of Oslo. The purpose of the pilot was to transport seaside visitors from the nearest bus stop or private car parking facility to a recreational area close by the beach. The aim was to remedy present traffic challenges during summertime, when there are a lot of visitors in the area, while the number of parking spots in the vicinity is limited. The test site comprises a 1 km long public road section with mixed traffic, and the passengers were served by two automated shuttle buses from EasyMile (EZ10, 2. Gen). The pilot was running a nonstop service 8 hours a day during the summer of 2018. A total of 9.300 km and 10.000 passengers were covered. The pilot activities emphasised surveys of user experience and public acceptance among the inhabitants in the area, focusing on the potential impact of automated mobility services in an urban development and land use perspective.

2.3   The Gjovik Pilot

The Gjovik pilot comprises a small-town centre shuttle service that was run in the summer of 2018. This pilot stands out because of some major start-up problems: The EasyMile (EZ10, 2. Gen) vehicle was exposed to several mechanical break downs due to the demanding topology of the road system. This led to pilot activities being delayed and cut down several times, resulting in only 161 km driven and 449 passengers served. However, a special interest was put in technology readiness issues and development, contributing to improvements in both vehicle software and hardware, as well as lessons learned for future pilots.

2.4   The Kongsberg Pilot

The Kongsberg pilot is probably the world's most advanced pilot, launched in October 2018 and still running. The test site comprises a 2,5 km long road section with mixed traffic and is also including a control operation centre. The pilot environment includes hilly roads and an extreme cold and snowy winter climate. Two EasyMile (EZ10, 2. Gen) shuttle buses serve passengers between the railway station and the business and college area of town, all year round. The automated shuttle buses are now incorporated and running as part of the regular daily bus service from the local public agency. By August 2019, a total of 3.440 km and 2.093 passengers were covered. The automated (and electric) vehicles replace a large diesel vehicle at times of day when traffic is low, and the capacity of a large bus is redundant. The Kongsberg pilot aims to achieve industrial growth through applied autonomy in the transport system, focusing on business development and application of innovative solutions in public and private collaboration.

2.5   The Oslo Pilot

A coordinated fleet of automated shuttle buses have been running as part of the public transport system in the city of Oslo since May 2019. By January 2020, a total of 9.300 km and 22.000 passengers were served by two shuttle buses from Navya (Arma). Since then, three more vehicles are put into operation in the capital area. The Oslo pilot is run by the public transport agency, aiming to prepare the customers for future services in an integrated mobility perspective. Considerable effort is put in user involvement and acceptance studies.

Although the pilots vary in terms of concept, size, technology, environment, target groups and business models, each one brings unique and relevant experience to the SmartFeeder project. A summary of pilot characteristics is presented in table 1.

Table 1: Automated shuttle service pilots included in the SmartFeeder studies.

	Forus	Fornebu	Gjovik	Kongsberg	Oslo
Pilot concept	First and last mile for work journeys	Leisure facilities in residential areas	Small-town centre shuttle service	The world's most advances pilot	Bus fleet coordinated by the PTA's operations
Context	Connecting job location and public transport in Forus Business Park	Shuttle between parking/bus stop and beach area	Technical challenges gave only 18 days of operation	Winter operations, and included in the PTA's daily bus service	A fleet of five shuttle buses in the capital area included in the daily bus service
Time	June – Dec 2018	June – Aug 2018	July – Sept 2018	Oct 2018 – still operating	May 2019 – still operating
Vehicle	EasyMile EZ10, 1. Gen	EasyMile EZ10, 2. Gen	EasyMile EZ10, 2. Gen	EasyMile EZ10, 2. Gen	Navya Arma
Distance	5.000 km	9.300 km	161 km	2.500 + km	10.500 + km
Passengers	6.000	10.000	449	5.000 +	25.000 +
Special interest	User acceptance and traffic safety	Initiated by urban real estate developing	Technical maturity and functionality	Business model and industrial growth	Preparing customers for future mobility solutions

3. EVALUATION METHODOLOGY

The SmartFeeder research team has developed a framework for impact assessment within a theory-driven evaluation approach. The evaluation process is driven by a conceptual model of how the automated shuttle services are expected to operate, see Figure 2.
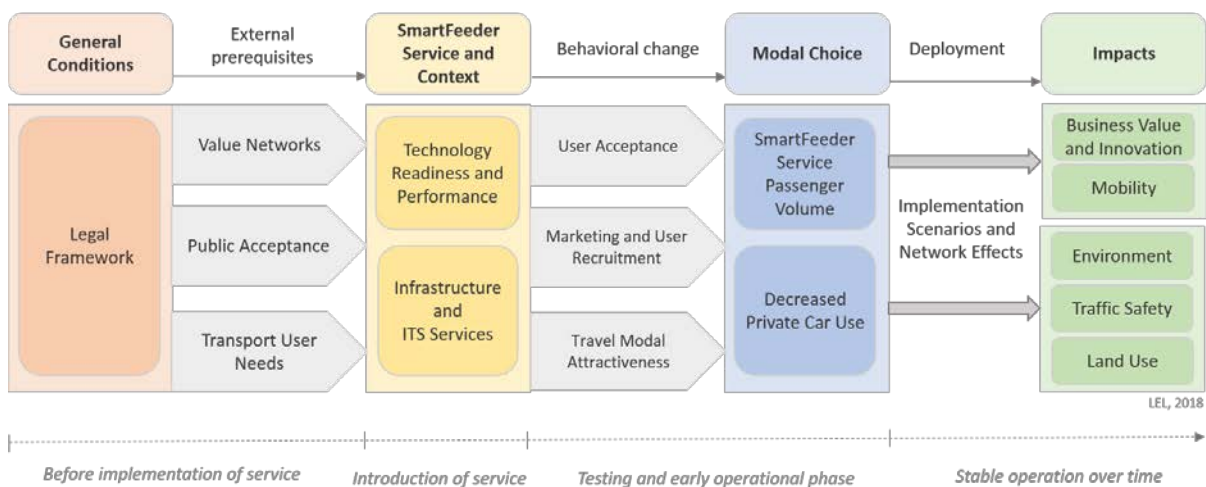

Figure 2: The SmartFeeder evaluation model

The evaluation process increases the understanding of how the automated mobility services operate and contribute to immediate change and long-term impacts on traffic safety, environment, travel patterns and user acceptance among other aspects. The influence of contextual factors is included, as it is recognized that potential barriers and success factors are likely to mediate the outcome. Although using a common evaluation framework, the individual study designs are tailormade for each pilot and test site. The work includes both qualitative and quantitative methods, like user surveys, interviews and analyses of passenger statistics and operating data from vehicle manufacturers.

The purpose of the SmartFeeder evaluation methodology is to generate comprehensive and applicable knowledge on best practice and constraints for future deployment of automated mobility services. The strength of this theory-driven approach are discussed in Lervåg (2017) and include the assessment of causal effects that produce knowledge of why the automated mobility service works or not, and what parts of the implementation and contextual factors that contributes to the observed effects. Furthermore, it has a formative capacity to include the incremental improvements throughout the smart mobility service life cycle, contributing to efficient use of development and implementation resources in the pilot projects. An additional advantage is the practicality and methodological flexibility, which leverage the data samples and research material by combining theory-based and experimental analysis.

4. RESULTS AND LESSONS LEARNED
Consecutive studies and impact assessments of the progressing pilots have generated applicable knowledge based on the pilot experiences and accomplishments. Constraints and prerequisites for beneficial implementation of automated mobility services are addressed, including technical, legal, organizational, and societal challenges.

A summary of relevant results is presented in the following sections.

4.1   Legal framework and regulations
The legal framework for testing of highly automated vehicles on public roads became effective by January 2018, including several regulations concerning requirements for the application process, the vehicle, the automatic system, vehicle registration and assurance, the test site, a risk analysis, and the operator. An assessment of the legal aspects, as well as preparation and approvement of the first pilots, gave input to a few recommendations to make the application process more efficient:
- An introduction and dialogue meeting should be offered by the National Public Roads Administration (NPRA) before the application process starts. The applicant should use a check list prepared by the NPRA to make sure the requested information is present and complete.
- Standardised templates for the vehicle information, route description and risk analysis would be beneficial. The template for vehicle information should be

flexible and frequently updated reflecting the rapid development of software and hardware.

- A local test forum should be assembled, with participants from police, road and rail authorities, and traffic managers. The test forum should have the mandate and authority to support the applicant when preparing the application. Activities should be based on national guidelines to ensure equal support and recommendations independent of the pilot location.

4.2   Technology readiness and performance

Automated shuttle buses are still in an early stage of the innovation process, with limitations concerning functionality and technological maturity. Nevertheless, the realisation of five pilots in mixed traffic on public roads has succeeded. The pilots include rather complex traffic environments in terms of extreme winter conditions, demanding topology, and interaction between different road users. The pilot activities have gained valuable operational experience concerning among other factors local and general requirements for road and infrastructure maintenance. Furthermore, the pilots have contributed to actual improvements in software and hardware for the vehicle producers and set the terms for further product development in line with northern climate and conditions.

In situations of interaction with other road users, automated shuttle buses currently have four distinct weaknesses:
1. A poor ability to merge, enter highways, expect lane change, and interpret a yield situation (left turn).
2. No consideration of their own size (hight/length)
3. A lack of ability to notify, negotiate and communicate their own intentions
4. A lack of ability to give way to emergency vehicles

Developments in sensors, artificial intelligence (AI) and deep learning are important to achieve higher speeds within the limits of safety and passenger comfort and enable use in all types of traffic environments. Recommendations for further development of technology and functionality involve moving the operator from the vehicle to a control centre for remote monitoring and operations and improving and adjusting sensors and algorithms for smoother interaction with infrastructure and traffic.

4.3   Traffic safety

There are currently no fatal or police-reported accidents involving automated shuttle services in Norway, despite extensive testing in a complex urban traffic environment. This might partly be due to the testing being well regulated and taking place at low speeds. New types of accidents might occur due to misunderstandings and impatience because the automated vehicles drive unexpectedly conservative and law-abiding compared to the conventional traffic culture. Automated vehicles might for instance require a rather long critical time headway before turning left at an intersection, and they will always stop at a yellow traffic light. Reported incidents by the pilot operators in Norway includes:

- Potentially hazardous overtaking performed by private cars, as the automated shuttle buses drive at low speeds. Yet, overtaking has not resulted in traffic accidents so far.
- Unmotivated stops of the automated vehicle may occur due to poor internet connection or disturbance if the sensors. Vegetation, trees and infrastructure, and even snow, heavy rainfall and fog might interfere with the bus sensors and prevent driving in autonomous mode.
- Cyclists or other road users violating the safety zone around the vehicle, might cause frequent abrupt stops representing a safety challenge for the passengers inside the shuttle bus.

International experience with highly automated vehicles in general, suggests that automation is likely to increase traffic safety, despite new challenges in the interaction between autonomous vehicles and other road users. The technology development will play a crucial role in the future safety impact of automated vehicles, as AI and deep learning will provide the basis for global learning and incremental improvements from every single incident.

4.4   User Perspective
During the project period, a national study of social acceptance of automated shuttle buses was carried out, as well as several user surveys related to the pilot activities (Roche Cerasi, 2019). The research studies report a positive development in terms of increasing user acceptance and trust in automated mobility services. Passengers are overall satisfied and feel safe – even in experiments without a host on board. There is reason to assume that automated mobility services that are perceived to be beneficial and simplify people's everyday travels, will be utilized. Current restrictions in vehicle speed and capacity are however limiting the present transport benefits for users today. Going forward, it is important to tailor mobility services that meet actual user needs and a real transport demand beyond the pilot activities.

4.5   Innovation and Business Development
The SmartFeeder project has developed a generic model of the value network of automated shuttle services, followed by specific descriptions of value networks and supplementary ITS services for the various pilots. The value network is defined as a web of relationships that generates economic value and other benefits through complex dynamic exchanges (both tangible and intangible) between individuals, groups, or organisations (Allee, 2000). Relevant service domains include transport services, infrastructure services, services related to transport means (vehicles), charging services, support and communication services and ITS services (information, booking and ticketing). Furthermore, opportunities for business development have been identified with regards to local advantages in an international market. The need of collaboration between complementary actors and services, and between private industry, government, city planners and public transport authorities is pointed out.

5 CONCLUSIONS

So far, the piloting of automated mobility services is merely an arena for developing and learning about future mobility solutions. It is not yet implemented as large-scale realistic transport solutions, and as of today, it is not possible to reveal any effects or impact on travel patterns. Any assessment of societal impacts must take into account that both technology, services and context are subject to continuous and rapid development. Nevertheless, piloting of new mobility solutions provides valuable and applicable knowledge for both policy makers and technology providers. Real life testing in complex environment and with real users contributes to identify limitations and need for further developments in terms of technological, legal, organisational, and societal aspects. Furthermore, it points out best practice and provides experience needed to succeed in a future transport system.

In the next phase, emphasis should be placed on tailoring solutions that meet a real transport demand, followed by large-scale piloting in relevant market segments where short-term gains and long-term benefits can be reaped.

BIBLIOGRAPHY

Allee, V. (2000), Reconfiguring the Value Network. Journal of Business Strategy, Vol. 21, N4, July-Aug 2000.

KPMG (2019), Autonomous Vehicles Readiness Index. Assessing countries' preparedness for autonomous vehicles. KPMG International.

KPMG (2020), Autonomous Vehicles Readiness Index. Assessing countries' preparedness for autonomous vehicles. Assessing the preparedness of 30 countries and jurisdictions in the race for autonomous vehicles. KPMG International.

Lervåg, L.E. (2017), Impact assessment of connected and automated transport services: Moving from the method-driven tradition to a theory-based evaluation approach. Scientific paper, ITS World congress in Montreal, 2017.

Roche Cerasi, I., (2019), Public acceptance of driverless shuttles in Norway. *Transportation Research Part F: Traffic Psychology and Behaviour*, 66 (2019), pp. 162-183.

SAEJ3016 (2016) Surface vehicle recommended practice – Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles, SAE International, 2016.