

# DRIVE : SWEDEN



## Shared Shuttle Services S3 – phase 2

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## 1 Summary

This report is about the second phase of Shared Shuttle Services S3 project. The project is part of the KRABAT project and partly financed by Vinnova through the Drive Sweden program. This phase of the project aims to incorporate the autonomous shuttles into commuters' daily life; the shuttles are placed between a parking lot that is further away from the office area and the public transport hub at the Lindholmen area in Gothenburg, Sweden. This way, commuters can either use the shuttle service to reach the parking lot or to the bus station to/from their offices. Besides, the shuttles are, for the first time, integrated into the regional public transport system. Passengers can search for and receive traffic information through public transport provider Västtrafik's app. This integration and the 5G network tested in this phase facilitate a wider application with the autonomous shuttles. For example, communication with vulnerable road users and integrated traffic information in other digital platforms. The shuttle service was opened to the public from the middle of January to the end of June 2021. User study and the research of business cases are carrying out in parallel.

## 2 Swedish Summary

Rapporten handlar om andra fasen av Shared Shuttle Services S3-projektet. Projektet är en del av regeringens samverkansprogram "Nästa generations resor och transporter" och finansieras delvis av Vinnova genom Drive Sweden. Fas 2 av S3-projektet syftar till att införliva de autonoma bussarna i användarnas dagliga pendling genom att ge bättre förbindelse mellan pendelparkering (parkering som ligger lite längre bort), kontorsområdena och kollektivtrafiknavet. På det sättet kan pendlare antingen parkera bilen på parkeringen eller åka kollektivt och sedan använda den självkörande minibussen för att komma till och från kontoret. Dessutom har minibussarna för första gången integrerats i det regionala kollektivtrafiksystemet. Passagerare kan söka efter och få trafikinformation via kollektivtrafikleverantören Västtrafiks app. Denna integration och 5G -nätverket som testades i projektet öppnar upp för en mångfald av applikationsmöjligheter med självkörande bussar. Till exempel kommunikation med oskyddade trafikanter och integrering av trafikinformation med andra digitala plattformar. De självkörande minibussarna var tillgängliga för allmänheten på Lindholmen från mitten av januari till slutet av juni 2021. Användarstudier och arbetet kring business case pågick parallellt.

### 3 Background

Deployment of autonomous shuttles is undoubtedly gaining importance, where many actors are experimenting with various services to improve and find new applications and business cases. The autonomous shuttle sector has thus far been owned and spearheaded by start-ups and new players within the mobility landscape, but larger and more influential actors are now joining the race as the technique gain interest and successively penetrates the transportation industry. Besides, cities have also started to show their interests as these solutions can potentially be used as a first and last mile transport solution.

A growing population in urban environments increase the importance of strategic and efficient use of existing land and road infrastructure. For example, the Lindholmen area of Gothenburg faces issues of rapid development to hold more residential and commercial units. Parking space has become limited and thus there is a need of new transportation solutions to maintain its accessibility and further contributing to Gothenburg becoming a “Smart City”. S3 phase 1 was conducted to introduce autonomous shuttles as a potential solution to these issues.

Deliverables and new learnings from S3 phase 1, with shuttle services up and running in Chalmers Johanneberg Campus and later also in the Lindholmen area, are important for the upcoming mission of taking the autonomous vehicle closer to its full potential. During phase 1 of S3, very valuable lessons were also learned by going through the application processes and necessary setup procedures to get the vehicles on the road.

The Lindholmen pilot in the later part of phase 1 is unique due to its partnership with real estate developers, where Göteborgs Stads Parkering operates the parking sites owned by Älvstranden Utveckling. Employees of the rapidly developing research hub Lindholmen Science Park are provided with an alternative to close the gap between a distant parking lot and a point of interest where parked vehicles are avoided. However, there are still some essential functions missing for full accomplishment of autonomous drive, where ability to drive without an on-board host is one of them. Furthermore, the service is still limited to low speeds of some 18 km/h. Addressing these functions is expected a necessary part in the second phase of S3 to create a functional business case and to make autonomous shuttles an attractive last mile alternative for car owners, according to the preliminary results of phase 1. User experience become especially important in the second phase, where enhanced reliability as well as real time information of the shuttle’s whereabouts serve to upgrade the service from an operationally functional pilot to an attractive mode of transportation in the area.

## 4 Project setup

### 4.1 Purpose

The major purpose of the second phase of S3 is to understand what role the autonomous shuttle plays in today's transport system and what mobility needs it can supplement to help the city become more sustainable. In this phase of the project, the purpose is to understand if the autonomous shuttles can encourage commuters to take public transport, or to park their cars at a remote parking (Park-and-Ride) instead of the overly crowded parking lots close-by their offices. This way, the autonomous shuttles can offer better accessibility to the office area by public transport or by car, and therefore can reduce the amount of car driving in the center area of Lindholmen, Gothenburg.

The aim is to make public transport more versatile and parking further away more convenient. In both cases, the results could be to reduce the need for cars in dense areas.

### 4.2 Objectives

Objectives of the second phase of Shared Shuttle Services S3 have been slightly altered. The reason behind this change is due to the original operator *Autonomous Mobility* left the project and Keolis AB came into the project as the operator for the autonomous shuttles. As the result, some changes were made in regards of the goal of the project and deliverables.

The project will design and execute a public pilot of shared shuttle services with the following objectives:

1. Applying for approval and testing the Navya Arma at a higher speed (over 18 km/h)
2. Investigating and developing prerequisites for having safety driver outside the vehicle. If possible, also testing this in limited traffic environments at Lindholmen.
3. Building a reliable and traveler friendly route with real-time information to the passengers.
4. Facilitating user functionality through real time communication technologies

### 4.3 Project period and budget

Shared shuttle services S3 project started after the summer in 2019 and was supposed to be finished in 2020. However, due to the pandemic and the change of operator, the project was then decided to be prolonged to June 2021. The total budget of phase 2 is approximately 13 million SEK.

Impacted by the pandemic, the official preparation for the permit to run the shuttle pilot started in the July 2020<sup>1</sup>. The service officially started in January 2021 and continued to June 2021.

### 4.4 Partners

The consortium consists of Chalmers, Ericsson, Göteborgs Stads Parkering, Härryda kommun, Johanneberg Science Park, Keolis Sverige AB, RISE, and Västtrafik.

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<sup>1</sup> Due to impacts of the COVID-19 pandemic, the preparation phase has been delayed about six months. The delay was mainly due to the change of operator for the shuttle service.

## 5 Method and activities

Operative activities carried out in this project and the partners involved are listed as follows:

### **WP1 Project management and coordination (RISE)**

Fulfilled actions:

- i) Bi-weekly project meetings with the core working team
- ii) Steering committee meetings quarterly

Deliverables:

- i) Project agreements among the project partners
- ii) Three status report to KRABAT (Nov 2019, May 2020, and April 2021)
- iii) Project report for phase 2

### **WP2 Application process (Keolis, Göteborgs Stads Parkering, Västtrafik)**

Fulfilled actions:

- i) Preparation for the route: Organizing and preparing the physical infrastructure along the route, which includes placing the temporary bus stops, placing lidar markers, organizing the parking lot and the infrastructure required, pruning the street trees, removing or adding barriers along the route, and installing the GNSS-station.
- ii) Communication with the landowners: Making sure the land can be used for the shuttle service during the pilot period and no construction projects would interfere with the route.
- iii) Application for the permit: The operator of the service, in this case Keolis, applies for the permit from the Swedish Transport Agency to run the pilot.
- iv) Plan for rerouting: Due to the interferences that might happen during the later phase of the pilot, the core working team has planned a separated route to cope with this situation. Luckily, the construction project did not impact the route severely in the end.

Deliverables:

- i) The official permit to run the autonomous shared shuttle service until the 31 December 2021 (*Tillstånd att bedriva försöksverksamhet med automatiserade fordon*)

### **WP3 Operation of self-driving shuttle bus (Keolis, Västtrafik)**

Fulfilled actions:

- i) Two vehicles in daily operation in mixed traffic during weekdays from 07:30 to 17:30 for at least four and a half months. Duration extends corresponding to the downtime.
- ii) The autonomous shuttles are part of the regular public transport and can be searched by line 56 in Västtrafik's traffic information app
- iii) Report on prerequisites for operating without an onboard driver

Deliverables:

- i) Report on prerequisites for operating without an onboard driver

- ii) Monthly report on the status of the operation (e.g., the number of passengers, incidents that hinder autonomous driving)
- iii) Real-time traffic information of the shuttles on Västtrafik's app

#### **WP4 Real-time communication (Ericsson, Keolis, Västtrafik)**

Fulfilled actions:

- i) Investigate and install the additional communication equipment and sensors to connect the shuttles to the 5G network ExperiCom
- ii) Test communication with vulnerable road users through the network (V2X communication)

Deliverables:

- i) Traffic data is available on the Drive Sweden Cloud through Västtrafik's backend
- ii) Shuttles are connected to Ericsson's 5G network ExperiCom

#### **WP5 User analysis (RISE)**

Fulfilled actions:

- i) Quantitative data collection and analysis
- ii) Qualitative data collection and analysis
- iii) Initiation and supervision of master's thesis project

Methods:

- i) Questionnaire study
- ii) Semi-structured interviews
- iii) Test of computer vision enabled data collection methodology (i.e., Univrse application)

Deliverables:

- i) Presented results at KRABAT event and dedicated S3 digital conference
- ii) Master's thesis on interaction for people with cognitive impairments

#### **WP6 Business models (RISE)**

Fulfilled actions:

- i) Development of various deployment scenarios for autonomous shuttles
- ii) Qualitative analysis

Methods:

- i) Stakeholder analysis
- ii) Desktop studies
- iii) Questionnaires
- iv) Focus group interviews

Deliverables:

- i) Results presented at dedicated S3 digital conference
- ii) Report on business model hypotheses

## **WP7 External engagement (RISE, Göteborgs Stads Parkering)**

Fulfilled actions:

- i) Support the shuttle service operation: Producing communication materials such as press-release, introduction film and photos, information sheets at the bus stops and communication with the potential users.
- ii) Göteborgs Stads Parkering issued incentives in terms of a lower monthly parking fee at 500 kr<sup>2</sup>/month (compared to 1000 kr/month in nearby parking lots at Lindholmen) and lower hourly rate
- iii) Communication with users who have a monthly card for parking at the nearby parking lots
- iv) Negotiate with Navya about the accessibility of data
- v) Participated and presented in conference Beyond 2020 and KRABAT's digital conference
- vi) Hosted and presented the project results in a dedicated S3 digital conference

In addition to the operative activities, several research actions have been carried out in this phase of the project. In this section, research methods of these specific actions are presented.

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<sup>2</sup> Swedish krona

## 6 Results and Deliverables

In this section, the results and deliverables promised in the application area addressed.

### 6.1 Permit application process and preparing the pilot sites

6.1.1 Permit application and communication with Swedish Transport Agency (STA)  
Keolis sent in a request to open a case for the permit on June 25, 2020. The process describes as the following:

- i) Start with Letter of interest<sup>3</sup>:  
The STA records a registration number for our case **TSV 2020-5673**. This is the number to refer to in all the dialogue with the STA.
- ii) Dialogue with between STA, operator Keolis and manufacturer Navy:  
The purpose of the dialogue is to ensure a good understanding of the process for all the parties involved. The process is interactive and requires engagement from all the actors involved.

Two main tests are crucial for the decision of the permit: the Factory Acceptance Test (FAT) and the Site Acceptance Test (SAT). The FAT in this case was carried out by the manufacturer Navya, and since the vehicle model Arma has already been granted permit before, the process went smoothly. The SAT test is normally carried out by the STA on site. However, due to the situation with the pandemic, Keolis used instead four different cameras to capture the route from different angles, inside and outside of the vehicle, and from the front side and from behind of the vehicle. The films are then used as the material for STA to assess the traffic situations with the autonomous shuttle.

- iii) The interactive process:  
After reviewing the materials, some minor changes are requested by the STA. The **temporary permit** was issued once the assessment board was satisfied with the results. The temporary permit allows the operator to start doing necessary testing, programming on the route, and training the safety drivers.
- iv) Iterative process for the official permit:  
After all the improvements with the vehicles were made, traffic safety and driver training, a new set of films are made with the cameras to visualize the results for another round of the SAT.

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<sup>3</sup> General information can be found at:

<https://www.transportstyrelsen.se/en/road/Vehicles/self-driving-vehicles/>

[Application form:](#)

<https://www.transportstyrelsen.se/en/Forms/Road/Vehicle/letter-of-interest---permit-for-self-driving-vehicles/>

<https://www.transportstyrelsen.se/globalassets/global/blanketter/vag/english/tsv7100-letter-of-interestt.pdf>

During the assessment process Keolis has received comments regarding the traffic situation at the crossroad between Regnbågsgatan and Götaverksgatan. At the crossing, the vehicle was first decided to be driven in the manual mode for safety reasons. However, this decision was dropped later-on after long discussion with the committee. The official permit with amendment for the pilot was issued on the 21st of January 2021.

In this project, a permit for driving faster than 20 km/h is however not possible to issue because of the maturity level of the technology. The same reason applies to receiving a permit to test without onboard driver on public roads.

### 6.1.2 Pilot site preparation

After discussion with stakeholders and the project group, we came to the decision to run the route that connects Hugo Hammars kaj parking lot and the bus stop Regnbågsgatan (figure 1). The consortium was considering the possibilities to extend the route downward Götaverksgatan. However, due to the limitation of space and to improve the efficiency of the shuttle service, the consortium decided to keep the route simple and accessible.

The infrastructure preparation includes:

- i) The land for placing the bus stops
- ii) Temporary bus stops
- iii) Installation of lidar markers on proper objects
- iv) Clear the route of potential obstacles (pruning the street trees and the grass)
- v) Separate the lines if necessary
- vi) A backup route in case of construction (see 6.2.3 *Alternative routes*)



**Figure 1:** The map of the route for line 56 autonomous shuttle service

## 6.2 Operation and prerequisites of driving without a safety driver

### 6.2.1 Operation

The average speed of the shuttles over the pilot period is slightly over than 19 km/hr. The accumulated commercial mileage is 5638 km, approximately 58 km per day. Due to the pandemic, the amount of the passengers of public transport has dropped significantly. As the result, the shuttle service has also had a hard time receiving passengers. During the period January 18 to June 24, a total of 1451 passengers have traveled with the shuttles.

As for the popularity of the bus stops, most activities (boarding or dropping off) were observed at the transit hub Regnbågsgatan and secondly, at the parking lot Hugo Hammars kaj.

### 6.2.2 Difficulties and solutions

Several obstacles occurred during the S3 pilot. The following section provides a summary of issues that we encountered and how they were resolved during the pilot.

#### **GNSS signal loss**

The GNSS signal loss happened occasionally, causing the vehicle to break, and in some cases, stop entirely of safety reasons. The main cause of the signal loss is the metal facades on the buildings in this area. During the project, this issue was temporarily resolved by using manual driving. However, in the future, this issue can be solved with adding transmitters in “confined” areas. Besides, the scaffoldings built around the construction objects also caused signal problems. A tighter communication with the construction companies and the landlords is crucial for avoiding these kinds of issues.

#### **Obstacles on the road**

Random vehicles or objects sometimes blocked the road during the day, for example, delivery trucks, containers, or even badly parked cars. Normally the drivers can easily bypass the random obstacles without concern, but the autonomous shuttle cannot carry out this task on its own. Manual takeover is required to tackle with obstacles randomly occurred on the road. To a certain extent, this problem can possibly be resolved by adding digital overtaking zones under specific conditions.

#### **Changes along the route**

The construction works mentioned above also caused some other problems. For example, the tarpaulin wrapped around the buildings for protection or the scaffolding around affect the autonomous shuttles’ ability to recognize the environment. This happened at two sites along the route during our pilot period. The solution was then either to remap the area or to drive manually at these sections. Due to the time limit and to cost concerns, the project adopted the latter solution.

#### **Weather conditions**

Extreme weather conditions can have negative impacts on the shuttles. As many other electric vehicles, the lower temperature limits the capacity of the batteries that used to power up the vehicles. Shorter ranges were observed during the wintertime. To make sure that the shuttles can be properly charged and stored overnight in a cold garage during the wintertime, several

small air heaters were used to keep all essential compartments warm. This measure allowed us to keep our uptime when it was -15-degree Celsius in the air.

In addition to the temperature, snowy days can also be challenging for the sensors. Heavy snows in the air and bigger snow piles on the road can be identified as obstacles and thus cause the shuttles to break or stop. However, when the weather condition becomes too extreme, the transport service should be cancelled for safety reasons no matter it is driven manually or automatically. This happened once during the pilot period.

6.2.3 Alternative routes

An alternative route was planned by the core working team to tackle the potential interference from the construction project close to the bus stop Anders Carlssons gata. If the construction work needed to start early, the route of the shuttle could then be separated into two loops; one shuttle goes from Hugo Hammars kaj to A Carlssons gata and the other one drives between A Carlssons gata and Regnbågsgatan (figure 2). In this case, the service can be retained to almost the same level and serve the mobility need it was intended to in the first place.

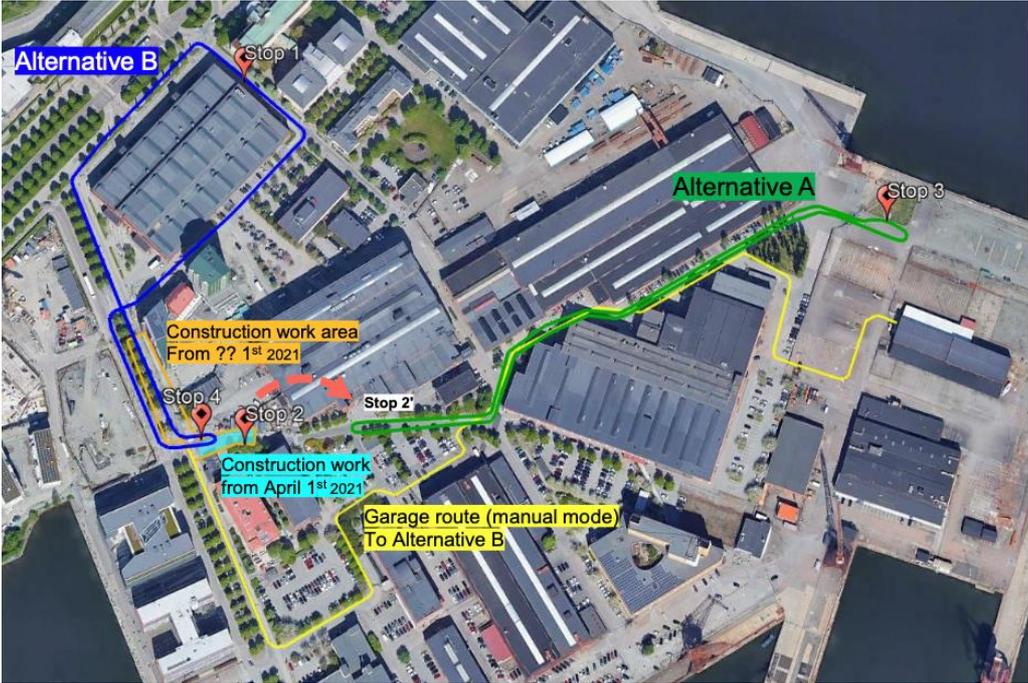


Figure 2: The alternative route to cope with the construction project. The blue line shows the loop between Regnbågsgatan and A Carlssons gata. The green line goes between Hugo Hammars kaj and to where the stop A Carlssons gata is today.

6.2.4 Prerequisites of driving without a safety driver

The STA has now opened for opportunities to run an autonomous vehicle without a safety driver onboard. However, in the short term, the technology is still not ready. Some requirements to be fulfilled are listed below. These requirements to a large extent focus on safety and the possibility to stop the vehicle when needed.

- Safety and especially ability to stop the vehicle remotely. This includes technologies related to cybersecurity to secure the communication between the vehicle and the control entity.
- The vehicle needs to be able to act more independently, meaning that the vehicle's ability to identify different objects and understand different traffic situations should be good enough, so that it can be make decision to break or stop to avoid risky or dangerous situations.

The two requirements in combination are the prerequisite for running pilots without a safety driver inside the vehicle. To ensure traffic safety is the foundation for these demonstrations. However, since the autonomous technology on the model Arma today still cannot fulfill the requirements, the project cannot therefore demonstrate driving without a safety driver on public roads.

### 6.3 Traffic information integration

One of the objectives of this phase of the project is to increase user-friendliness of the shuttle service, so that the users can easily incorporated this travel behavior into their daily routines. To do this, the project intends to integrate the autonomous shuttles into the regional public transport provider *Västtrafik's* normal traffic information flow.

The two autonomous shuttles were equipped with a simplified version of *Västtrafik's* onboard computers. These computers made it possible for *Västtrafik* to receive real time information from the shuttles. *Västtrafik* tested the whole process to integrate the connected autonomous shuttles into its system. The information that was incorporated to the system includes timetable service, geographical information, and real time information which is available on the app and at the bus stops indicating when the shuttles will appear. The integration also made it possible to see the shuttles on *Västtrafik's* webpage and to do a travel plan at *Västtrafik's Travel Planner app* and/or on the webpage. Users can find the trips from anywhere in Västra Götaland county to connect with route 56, the official line number for the connected autonomous shuttles in S3 project.

As an outcome from this integration in *Västtrafik's* system, it showed that it is possible to handle autonomous vehicles the same way as any other bus in *Västtrafik's* internal systems for vehicle information, traffic data and geographical information.

### 6.4 5G connection and V2X communication

The S3 shuttles were eventually connected to Ericsson's ExperiCom 5G network to enable connectivity and V2X communication.

Once the final route was agreed and approved in December 2020, Ericsson and Keolis performed a joint measurement of Ericsson's mobile network coverage as well as discussed with Keolis and Navya what extra communication equipment could be installed on the buses. A separate request whether any of the existing data collected by Navya could be made available to the S3 project was also made but unfortunately, never realized.

Network strength measurement revealed that additional radio coverage was needed to ensure satisfactory coverage. Analysis of potential new site locations was initiated.

The radio- and mobile network at Lindholmen consisted of three 5G mid-band (3760 – 3800 MHz) radio units and a 5G vEPC (virtual Evolved Packet Core). Two of the radio units were temporarily installed on a roof in the center of the S3 shuttle route (figure 3), and one radio unit was located at Ericsson’s premises at Lindholmen. The remote radio units were connected to 5G EPC via microwave backhaul (Mini-Link) (figure 3). The 5G vEPC was placed in data center in Ericsson premises at Lindholmen.

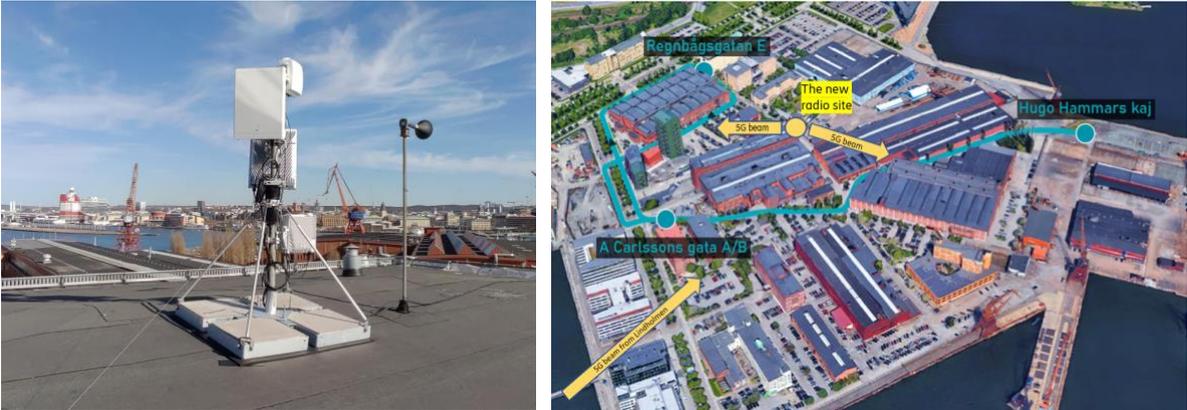


Figure 3: Image of the 5G EPC and location of the new radio site

At the shuttle, a 5G modem/router (E-Lins H900 / Quectel RM900Q module) was installed together with a Raspberry Pi 4 equipped with Adafruit GPS HAT. 5G vehicle antennas were mounted on the roof of the Navya shuttle, and GPS antenna was mounted inside the vehicle at a flat surface by the wind screen (figure 4).



Figure 4: Image of the shuttles and 5G antennas

The backend systems consisted of Ericsson Innovation Cloud (EIC) and a Network Supervision dashboard. These backend systems subscribed to vehicle and network data (MQTT topics) and presented the location data and network data in different Graphical User Interfaces (GUIs).

Network Supervision dashboard was used at Network Operations Center at Lindholmen to monitor radio characteristics and mobility, and this was a read-only presentation dashboard (figure 5).

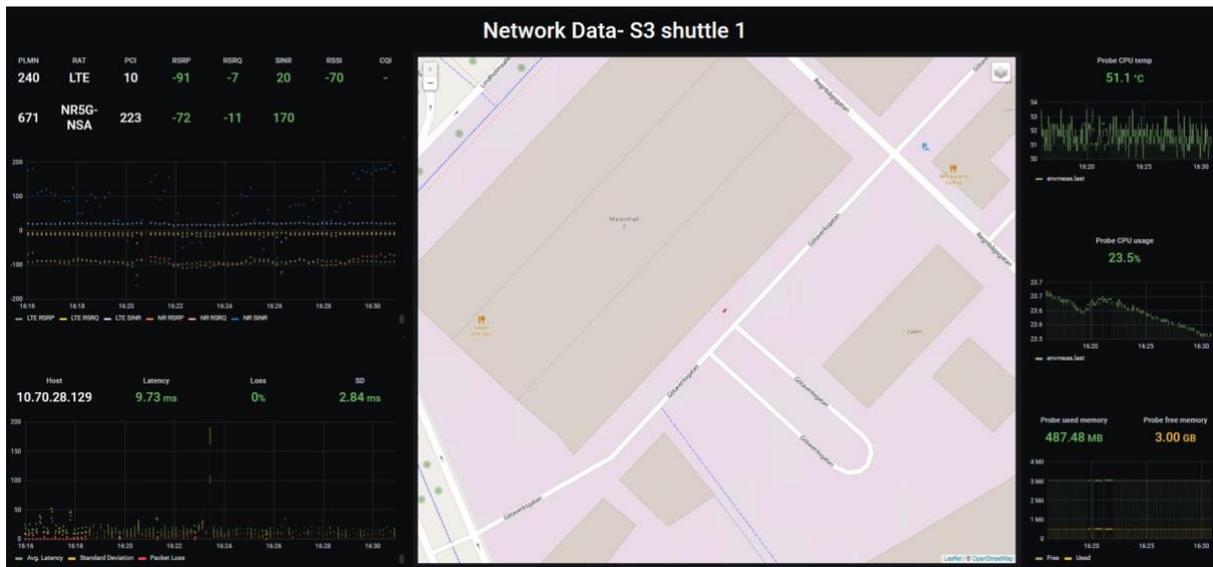


Figure 5: Network supervision dashboard

Ericsson Innovation Cloud, beside visualizing location of the vehicle, and network information at the particular location, also contains logic to trigger actions based on the location/heading of the reporting objects.

The V2X use cases tested in the S3 project related to protecting Vulnerable Road Users (VRU), e.g., bicyclists, road workers or pedestrians. The objects included were the S3 shuttles (shown as the vehicle icons in figure 6) and a connected VRU sensor represented by a road worker (vest icon in figure 6).

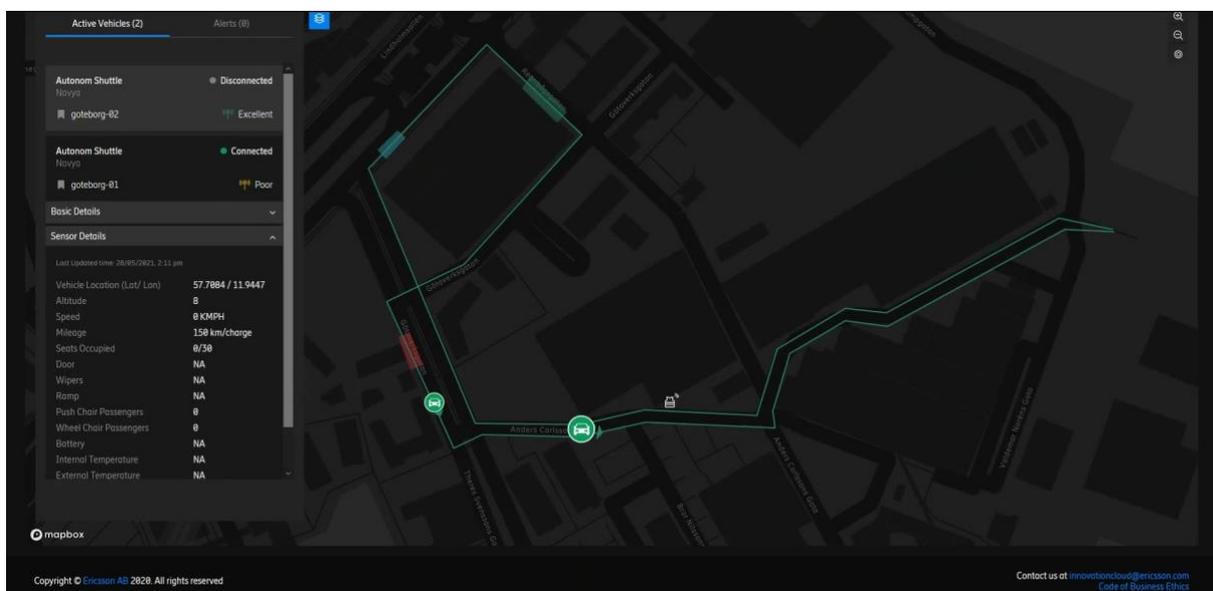


Figure 6(a): V2X test with vulnerable road users (the vehicle icons represent the autonomous shuttles, and the vest icon represents the VRU)

To trigger events, the logic in Ericsson Innovation Cloud supports two different kinds of geofences:

- *Static geofences* (green, blue, and red areas in figure 6) are coordinate-based and can represent areas where certain rules apply, as example reduced speed, no-entry,

emission-free zone etc. Static geofences can be applied around, for example, construction work areas, accident areas.

Notifications were sent over MQTT protocol to both vehicle and VRU sensor when entering and leaving a static geofence. In the vehicle and in Ericsson Innovation Cloud, notifications are transformed to audiovisual notifications (LED lights in front and back on safety vest as well as audio in earphones) as messages to the VRU sensor.

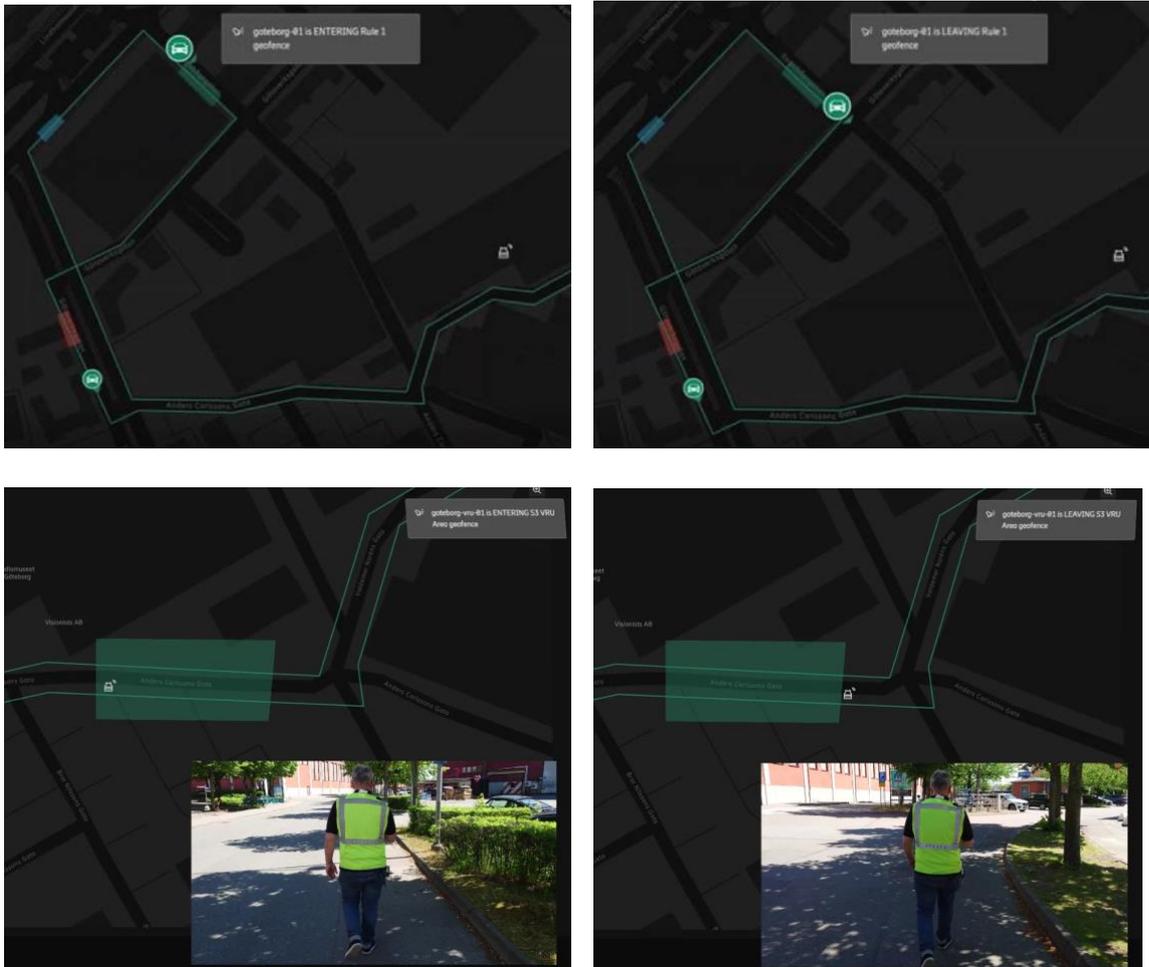
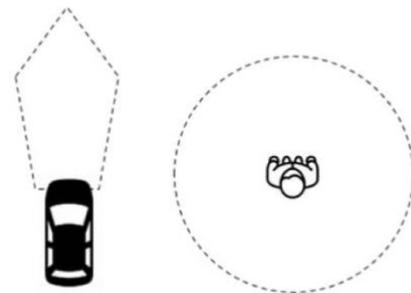


Figure 6(b): V2X test with vulnerable road users (VRU)

- *Dynamic geofences* are created around objects, instead of static coordinates, and follow the object as it moves. In S3 project, dynamic geofences were created in front of vehicles (in shape of polygon) and around Vulnerable Road User sensors (circular).

The area of the dynamic geofences is configurable.



Once a vehicle- and a VRU geofence overlap, notifications are sent to respective connected sensor (notification messages and audiovisual signal at VRU sensor) as well as in Ericsson Innovation Cloud.

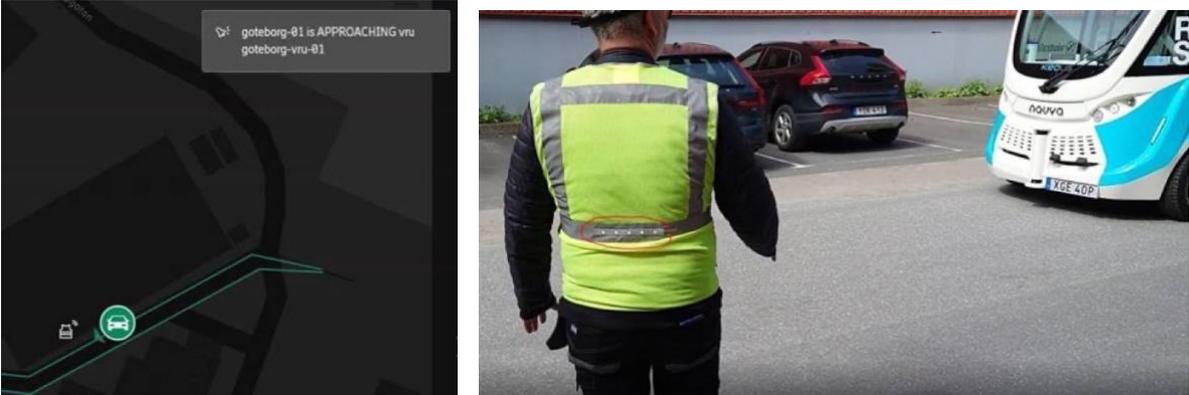


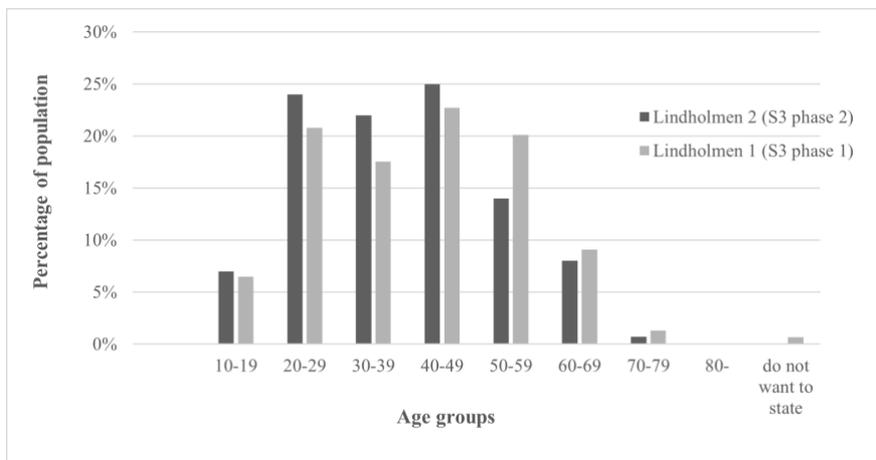
Figure. 6(c): V2X test with vulnerable road users

6.5 User study: Specific findings in this phase and other

This work package included questionnaire studies to investigate user acceptance of the AV shuttle services. Both S3 phase 1 and phase 2 (using the same type of vehicles both on different routes) were used as a basis for data collection among riders. Table 1 presents basic demographic and travel behaviors information. A total of 81 complete questionnaires were collected for the latest route (Lindholmen 2). For comparison, the figures also include results from the previously reported route in S3 phase 1 (Lindholmen 1). Overall, the population is similar between the routes with slightly more male respondents, most stating to be employed or student, a majority having tested the service once or a few times, as well as indicating to be among the early/middle when it comes to trying new products and services. Figure 7 also presents the distribution of age groups of the respondents. Ultimately, while we chose to include Lindholmen 1 results as reference, any deeper comparison is limited by aspects such as precise route location, service characteristics, evolving state and public understanding of the technology. The most notable difference between the samples is that Lindholmen 2 was collected during the COVID-19 pandemic with a dramatically reduced number of people visiting the area.

**Table 1:** Demographic and travel behavior information.

		Lindholmen 2 (S3 phase 2)	Lindholmen 1 (S3 phase 1)
<b>Gender</b>	Male	61.7%	54.2%
	Female	38.3%	45.8%
<b>Main occupation</b>	Employed or self-employed	58,0%	37,8%
	Student	28,4%	43,4%
	Retired	5,0%	6,4%
	Other	7,3%	8,3%
	Do not want to say	1,3%	4,1%
<b>Number of times using the shuttle service</b>	1	60,5%	76,3%
	2-5	35,8%	21,8%
	6-10	3,7%	1,9%
<b>Days a week using public transport to the area</b>	0 days	28,4%	41,1%
	1 - 2 days	34,6%	12,8%
	3 - 5 days	28,4%	37,5%
	6 - 7 days	8,6%	8,6%
<b>Days a week parking in the area</b>	0 days	60,5	64,2
	1 - 2 days	35,8	6,2
	3 - 5 days	4,9	27,2
	6 - 7 days	3,7	2,4
<b>When it comes to trying new products/services, I am generally...</b>	Among the first	33,3%	35,7%
	In the middle	53,0%	46,8%
	Among the last	7,4%	7,8%
	Do not know	6,1%	9,7%



**Figure 7:** Respondents' age groups from S3 phase 1 and phase 2.

The more quantitatively assessed indication of user acceptance was based on a range of influencing factors. These factors were evaluated using at least one five-point scale (from -2 to 2) including opposite words (i.e., antonyms). As mentioned above, these user acceptance ratings are largely based on limited experience of testing the autonomous shuttle services. From this initial experience participants average scores indicate that riders view the service on the positive side of the scale for the majority of the provided acceptance factors (ranging from usefulness to hedonic motivation in figure 8), with only “service/vehicle characteristics” in terms of speed (fast/slow) yielding a lower rating. However, to reach overall user acceptance and a more continuous adoption of the innovation, there is arguably a need to see higher scores for this set of basic acceptance factors. Ultimately, these results represent an

attempt at a quantitative assessment of the user acceptance of the autonomous shuttles. The provided services score higher in terms of novelty factor (e.g., hedonic motivation) than for the more pragmatically oriented factors (e.g., performance/effort expectancy etc.), indicating a curiosity for the technology and new type of mobility service. As this novelty factor fades, there is a need to strengthen the more core service offer and service characteristics in order to reach adoption and meet the expectations of the participants stating a behavioral intention to use similar autonomous shuttle services in the future.

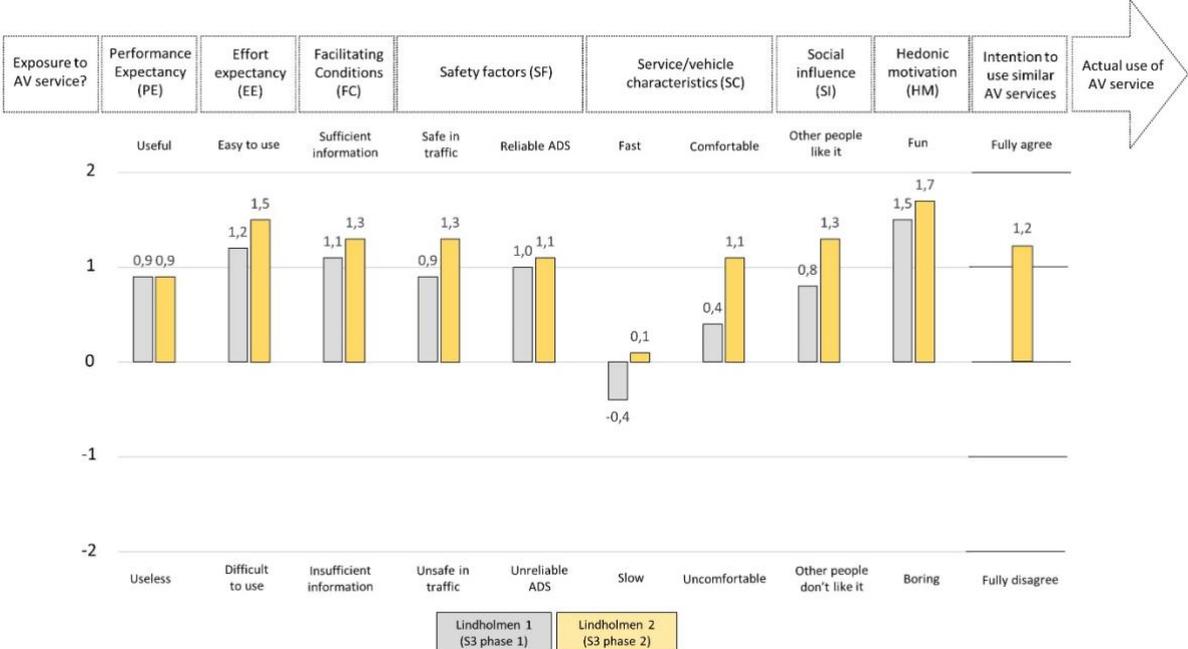


Figure 8: Respondents’ acceptance ratings from S3 phase 1 and phase 2.

The qualitative data collection provides complementary insights to the results presented above. Participants’ statements could be summarized in the following main reasons for wanting to use the AV shuttle service: 1) It is fun/exiting to try, 2) It is practical, 3) It takes less effort, 4) It protects me from bad weather, 5) It is environmentally friendly, 6) I want to support the AV development, and 7) It is free of charge. The reverse perspective (i.e., why not to use the AV shuttle service) could be summarized by, 1) It is not practical enough, 2) The route is not for me, 3) Takes more effort than alternatives (e.g., waiting time, easier to walk) 4) Safety reasons (including risk of COVID-19), 5) It is better to walk or bike instead, 6) I might need to be social during the trip (e.g., talking to the on-board steward or other passengers in the shuttle).

On the topic of the safety driver, most (7 of 10) still prefer to have that person on-board the shuttle. Motivations included that it “feels safer and makes sense in the current situation”, that “the software is not mature enough”, and that “without the person the bus would never be able to run due to snow, incorrectly parked cars, etc.”. However, riders also provided feedback in line with that “the whole point of the vehicle is that no additional staff is needed”. Regarding sharing the ride most (9 of 10) stated that they prefer to ride with other people or that it does not matter. Motivations included that it “depends on the time and place”, “does

*not matter, the main purpose is to take me from point A to B, not to socialize”, and that “Who does not miss other people in the pandemic!”.*

While the main focus has been on user acceptance in terms of service trials, the investigations also covered some perspectives of other road users and their interaction with the autonomous shuttles. Based on on-site data collection (i.e., asking pedestrians, cyclists, drivers in the vicinity of the shuttles), most road users (approx. 8 of 10) state a neutral or positive experience of the interaction. However, this was often based on limited experience and less ambiguous scenarios (e.g., clear who has right of way or larger distance between the road users). It is also important to note that the shuttles have an attentive on-board safety driver available for providing cues, and that the system is basically programmed to stop for any obstacle violating its comfort zone. Respondents described how the shuttles *“stops and makes a ‘pling’ sound”, “looks like a giant toy-car!”, “stops for everything rather than to drive”, “needs to better adapt to surrounding traffic”, or that “It will take some time to get used to, I don’t trust it but have seen that someone is there in control”.*

Following earlier initiatives on the topic of inclusiveness and accessibility (e.g., acceptance of people with visual impairment or people using wheelchairs), the current work package included a master’s thesis on acceptance for people with various cognitive impairments (see reference in section 8). One overarching theme is that stakeholders (including technology providers, service operators, public actors etc.) to a large extent face similar questions and considerations related to accessibility as for more traditional modes of public transportation. However, the AV shuttles services may introduce some unique challenges (e.g., safety/security, information related etc.) and highlight the extended role current drivers cover that goes beyond driving.

## 6.6 Business models

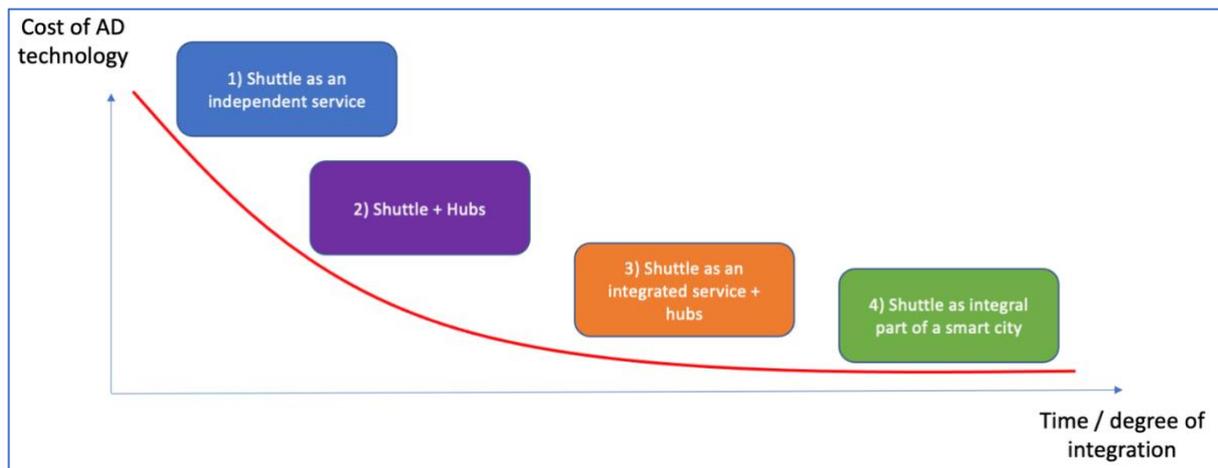
This work package sought to evaluate the business case for autonomous shuttles within the area of Lindholmen. Overall, the work package included the following aims and objectives:

To develop and evaluate business hypotheses for how autonomous shuttles:

- Can generate value for different types of travelers, organizations and their employees, and wider society
- Can be linked to digital interfaces for combined mobility services
- Could be fully financed and operated by a relevant actor/ organization.

### 6.6.1 Scenario development

As a first step within the work package, the project team developed a set of scenarios based on how autonomous shuttles may be deployed in the future. Altogether, four scenarios were developed based on predictions related to the falling cost of autonomous vehicle technology, parallel service developments and digitalization (figure 9).



**Figure 9:** Future deployment scenarios for autonomous shuttles in urban areas

**Scenario 1** focuses on the shuttle as an independent service, with existing (high) technology costs, a single, limited route and no integration with other mobility services such as public transportation, parking or MaaS. This scenario is roughly similar to that tested within the S3 project.

**Scenario 2** presumes an independent shuttle service that connects multiple mobility hubs within the Lindholmen area, enabled by lower technology costs and improved functionality (e.g., higher shuttle speeds, full autonomy). Each mobility hub is equipped with multiple mobility and ancillary services (e.g., grocery deliveries) in place of existing parking infrastructure, such that parking in the central Lindholmen area is more sparse.

**Scenario 3** is based on autonomous vehicle technology that has reached a certain degree of maturation: full autonomy is fully tried and tested and has been established as an international standard within the transport system, at a relatively low cost. Within this scenario other aspects of the transport system have undergone significant change when compared to the current status quo. There is a high degree of electrification, supported by a comprehensive charging infrastructure, and shared mobility services have to a large extent replaced private vehicle use. Within Lindholmen, these developments are reflected in a shuttle service that is fully integrated with other modes of transportation and by a radical reduction in parking infrastructure that has been replaced with a network of interconnected mobility hubs.

**Scenario 4** is a further extrapolation of the trends within the scenarios described above: autonomous vehicle technology has reached full maturation and is thus optimized within different transportation scenarios. Shuttles are one of many fully autonomous vehicle types that move without drivers as part of an interconnected transport system, optimized to deal with fluctuations in demand alongside weather and seasonal variations. A high degree of digitalization is reflected by the realization of smart cities, whereby vehicles interact with physical infrastructure as part of smart cities. Autonomous shuttles are used for work purposes and generate utilities for private citizens, with high utilization and constant use. Moreover, mobility services reflect integrations between what were previously separate industry sectors – public and private transportation, energy and telecoms.

Scenarios were developed and presented to internal project stakeholders to examine (qualitatively) issues related to “how” and “when” business models (and associated services) should be developed within the S3 project. To this end, project stakeholders argued the importance of assessing the business case related to scenario 1, that is, the shuttle as deployed within the project pilot. However, internal project stakeholders also demonstrated an interest in exploring how future developments may influence travelers’ interest in autonomous shuttle services. As such, we agreed to evaluate elements of scenarios 2 and 3 as a means to understand how an autonomous shuttle service could be deployed and what utilities it may generate.

6.6.2 Generating and evaluating business model hypotheses

To generate and evaluate business model hypotheses, we deployed an approach centered on business model development, inspired by the Lean Startup methodology. Using this approach, we developed and (to some extent) evaluated a set of hypotheses related to the key elements of a business model together with project stakeholders. These key elements focused primarily on value propositions, customer/user segments, with some consideration also given to cost structure and revenues streams. We elected to focus on these elements since the business model is at a very early development stage.

An initial step in this process was to identify and describe key customer and user segments that could potentially benefit from autonomous shuttles within Lindholmen, and to explore the types of utility that could be generated for these groups. After drawing up an initial list we then prioritized key customer and user segments based on our own estimations of their willingness to use and pay for a shuttle service (see figure 10).

Potential customers		Users	
Property developers	Property owners	Corporate tenants	Employees
			Students
		Housing associations	Residents
		Local businesses	Customers
			Tourists

Figure 10: Key customers and users of a proposed shuttle service

The initial list of hypothetical utilities included statements related to the possibility that an autonomous shuttle could:

- Facilitate first and last mile travel for a range of trips (e.g., commuting trips using public transportation)
- Act as a mobile meeting place for employees and business travelers
- Reduce the need for parking infrastructure within the Lindholmen area, particularly with regard to new property developments

- Support particular groups in particular tasks (e.g., grocery shopping for elderly residents)
- Act as a viable substitute for walking and cycling in bad weather and during the winter season

This list of prospective utilities was then evaluated during a digital workshop attended by the shuttle’s drivers. Initially our plan was to evaluate hypotheses with travelers that had used the shuttle service, but ridership numbers were prohibitively low due to the pandemic. As such, gathering an adequately large sample was not possible within the constraints of the project. Instead, we included shuttle drivers in our analysis as a conduit for travelers’ insights regarding the utilities and functionalities of the shuttle. We assessed out hypotheses using conjoint choice modelling, whereby respondents were asked to evaluate a set of service-related attributes that were arranged into bundles. Attributes included the channels within which the service is delivered; the extent to which the shuttle service is integrated with other mobility-related services; the frequency with which the shuttle travels; the opportunity to freeze tickets; whether or not the service includes a travel guarantee, customer support and a safety driver; and pricing. These attribute packages are shown in table 2.

**Table 2:** Bundled attributes evaluated during a workshop with safety drivers

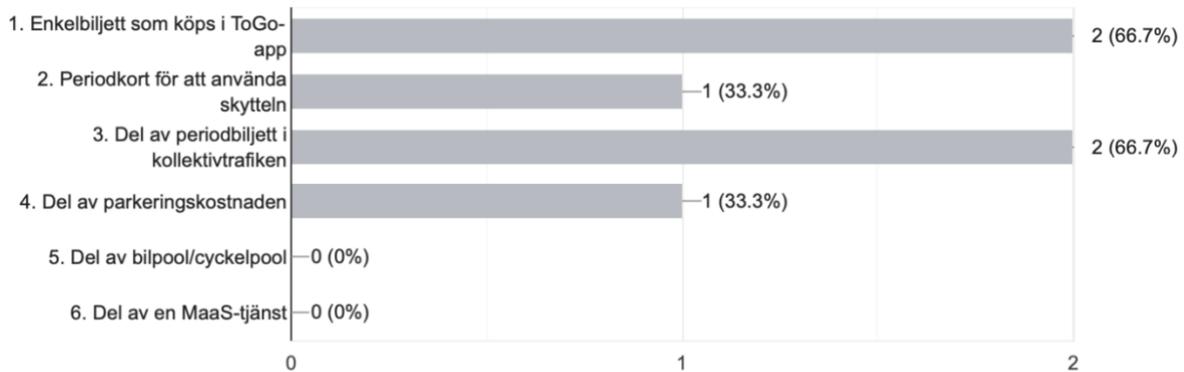
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
<b>Integration</b>	Single tickets via ToGo	Monthly passes	Part of PT monthly pass	Included in parking fee	Included in car club or bikeshare scheme	Included in MaaS service
<b>Frequency</b>	4 trips per hr	On demand	4 trips per hr	On demand	4 trips per hr	On demand
<b>Ticket freezing</b>	NA	Yes	No	No	NA	Yes
<b>Travel guarantee</b>	No	Yes	Yes	No	Yes	Yes
<b>Customer support</b>	No	Yes	Yes	No	Yes	Yes
<b>Safety driver</b>	Yes	No	No	Yes	No	No
<b>Price</b>	<b>22kr*/day or 3kr/min</b>	<b>149kr / month</b>	<b>+100kr/ month</b>	<b>22kr/day or 3kr/min</b>	<b>10kr / 30 mins</b>	<b>18kr / hour</b>

\*kr = Swedish krona

During the workshop respondents were asked to evaluate these attributes, both individually and as packages, and comment on their potential utility for travelers. Respondents argued for the following stated preferences:

Frequency	Four trips per hour was seen as satisfactory, apart from at peak times during which the shuttle should travel more frequently (e.g. every five minutes)
Ticket freezing	Unnecessary
Travel guarantee	Unnecessary
Customer support	Essential
Safety driver	Essential
Price	Varied responses – either a monthly pass for the shuttle at 149kr per month; 10kr per 30 minutes as part of a bikeshare scheme; or 18kr per hour as part of a MaaS service.

Respondents' overall evaluation of bundle attributes is shown in figure 11.



**Figure 11:** Respondents' evaluations of attribute bundles

Beyond the evaluation of individual attributes and attribute bundles, respondents commented on the functionality of the shuttle service and demonstrated similar perspectives to those highlighted in section 6.5. That is, shuttle drivers commented that the shuttle travels too slowly, that it does not fulfil scheduled timetables, and that the existing route is too limited to appeal to travelers within the Lindholmen area.

It should be noted that respondents did not find the prospect of integrating the shuttle service into other mobility services (beyond public transportation or parking services) particularly appealing. This may be for a number of contextual factors: a lack of awareness of novel services such as MaaS and/or a low response rate. Respondents found the prospect of the shuttle acting as a mobile meeting place and integrating other, non-mobility services (such as grocery and goods deliveries) with the shuttle service similarly disinteresting. Again, this may be due to a lack of awareness or an inability to visualize such possibilities. Respondents did however find that a reduction in parking opportunities within central Lindholmen, if such a development should occur, would imply that the shuttle service can become much more valuable for daily travel in the area.

## 7 Conclusions, Lessons Learnt and Next Steps

In this section, some challenges and lessons learnt are presented. Besides, there is also a list of Do's and Don'ts which contains some valuable takeaways from the S3 pilot.

### 7.1 Permit application process

#### **The main challenges:**

Generally, that it will take more time since it is an interactive process involving a team from STA that need to be fully satisfied with the behavior of the AV in its operation environment

#### **Lessons learnt from the process:**

It is a learning process for both the applicant for the autonomous vehicle pilots and the STA that issues the permit because of the novelty of the current technology. It is hard to foresee all the issues that might come along, so the STA has been cautious to guarantee traffic safety. Here are several tips that may help to smoothen the application process:

- 1) Plan for a period of at least 6 months
- 2) Ensure effective communication and dialogue with the STA during the process
- 3) Involve the vehicle manufacture in the dialogue and the application process from the beginning. There will be questions that need their support to answer.
- 4) It is important to show the STA that the autonomous driving technology can make the vehicle behave safely and smoothly in autonomous mode.

### 7.2 Operation at Lindholmen

The operation was carried out in a smooth way. The timetable was able to be fulfilled under normal conditions. However, there were many disturbances during the project like containers and big lorries that happened to block the way, and the most problematic of all, construction work. Arguably to carry out the operation under these circumstances was a real achievement.

### 7.3 Traffic information and V2X connection

From a connectivity and V2X perspective, we would have wanted longer time to evaluate and develop additional use cases. However, the two geofence based VRU use cases were completed satisfactorily.

Next step would be to implement additional V2X use cases as well as evaluate remote control over 5G network as an alternative to the safety driver onboard.

### 7.4 User experiences

User acceptance (and eventual adoption) of autonomous shuttle services is dependent on multiple factors. While there is a need to improve the technical capabilities and reliability of the automated driving system, it is equally important to reach a strong service offer and competitive mobility solution in comparison to other alternatives. The current project has been successful at offering officially open trials of early generations of autonomous shuttle solutions, providing valuable insights and a possible steppingstone for future trials and deployments of shared, electric, and automated mobility services. In terms of user acceptance and experience, it will be a continuous challenge to match the rapidly evolving autonomous vehicle mobility landscape to the needs and expectations of riders as well as other road users.

## 7.5 Business models

In sum, it would appear that demand (and therefore willingness to pay) for the shuttle service that was actually tested during the S3 project is relatively low. Aside for the effects of the pandemic, which meant that ridership numbers were significantly lower than expected, the existing service is seen as too slow and existing routes too limited to generate adequate utility for travelers in and around the Lindholmen area. If and when parking opportunities are significantly reduced, an autonomous shuttle service may prove to be valuable to travelers as a first and last mile solution, especially during the winter months and when bad weather prevails. The methods deployed to evaluate prospective business models also highlight the following lessons for future autonomous shuttle developments:

- Real-world piloting and testing are essential to assess business model hypotheses – especially those related to novel mobility concepts such as autonomous shuttles that are integrated with other novel mobility (and non-mobility) services
- Assessing willingness to pay for autonomous shuttles is similarly reliant on opportunities for travelers and other stakeholders to trial services on an experimental basis
- It is unlikely that mobility services which harness autonomous shuttles, as independent carriers or as part of integrated services, will appeal to travelers in open, real-world settings until the technology becomes much more mature. Shuttles must become faster, more cost-efficient and capable of performing more complex maneuvers in order to fulfil a broad range of travel needs.

## 7.6 Do's and Don'ts

Permit related:

- Prepare for the permit in good time
- Involve manufacturer in the homologation process at an early stage
- Be aware of the city development plans along the routes
- Start the dialogue with the landowners and the city authorities

Infrastructure related:

- It is important to learn about all the planned construction work in detail within the area because these projects will have an impact on the pilot by changing the current environment.
- Make sure that the project has valid and tested ways to contact the local stakeholders to be able to address current or upcoming problems.
- Make sure the local stakeholders, at least on a superficial level, understand how their actions can affect the autonomous vehicles to be able to minimize problems.
- The current autonomous vehicle technology allows shuttles to drive on the exact same spots all the time, which makes the asphalted pavement worn out much faster, especially at the spots where the shuttles make U-turns.
- Unexpected barriers that happened to be on the programmed route, including badly parked cars or temporarily parked cars, will stop the autonomous shuttles. This should be taken into consideration when planning the route and when communicating about the route to users and stakeholders.

- Make sure to take into consideration how costly alterations of the infrastructure will be if these alternations are perceived to have an impact of the operation of the autonomous shuttles. Make a cost-benefit analysis to determine what alterations of infrastructure should be addressed. Examine if these alterations are acceptable by the local government and by the operator of the road.

Connectivity related:

- Establish connectivity requirements as early as possible since additional network deployment can be time consuming (site planning and regulatory permits). This is a chicken-and-egg situation dependent on decision of final route.
- Secure access to as many data sources as possible from the outset – a foundation for elaborating on use cases.

Communication related:

- Communicate with the potential passengers about the bus station is important
- Communicate clear that there will be an autonomous shuttle pilot in the area
- Communicate to users that the project is part of technology development, so they have reasonable expectation from the presented technology
- Inform road users about the vehicle behaviors (e.g., runs at max. 20 km/h, stops when objects come to close to the vehicle, runs on a fixed route) to ensure smoother deployment and traffic safety
- Remind road users to keep a distance to the autonomous shuttles

## 8 Dissemination and Publications

Results from the S3 project has been spread through multiple channels listed below.

### Website:

[www.s3project.se](http://www.s3project.se)

### Conferences/seminars:

- i) KRABAT event 2021-04-28. Video available online:  
<https://www.drivesweden.net/en/events/results-vehicle-automation-pilots-within-krabat>
- ii) S3 Shared Shuttle Services online project event 2021-05-21 with around 30 participants

### Podcast/interviews:

- i) Framtidsmodellen interview with Drive Sweden (published by Dassault Systèmes)
- ii) Varberg for Future – interview with Peter Uppman at Region Halland

### Master's Thesis:

- i) Inclusive Design Guidelines for Information Needs on Autonomous Vehicles - *Exploring the Basic Requirement and Information Needs of People with Cognitive Impairment on Autonomous Vehicles*. Master's thesis in Interaction Design and Technology. Xinshu Li, Premthip Yaowapatsiri, 2021

### Supporting GPS research at Chalmers

- i) Förbättrad positionering med hjälp av GPS och Sensor Fusion, Examensarbete inom Data- och Informationsteknik, Marcus Alvefelt och Hampus Strömberg.

### Other publications:

- i) Beyond 2020 conference paper. "User acceptance of mixed-traffic autonomous shuttles in Gothenburg, Sweden. "

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**Drive Sweden** is one of the Swedish government's seventeen Strategic Innovation Programs (SIPs) and consist of partners from academia, industry and society. Together we address the challenges connected to the next generation mobility system for people and goods. The SIPs are funded by the Swedish Innovation Agency, Vinnova, the Swedish Research Council Formas and the Swedish Energy Agency. Drive Sweden is hosted by Lindholmen Science Park AB.