The Urban Lab of Europe!

JOURNAL

PROJECT

LINC - Transforming Urban Planning Providing Autonomous Collective mobility

Albertslund, Denmark

TOPIC

Urban mobility

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UIA EXPERT

LINC Project Journal 5 - finalizing the driver less shuttle tests

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The six months long test with self-driving shuttles at DTU Campus has just ended, and in journal 5 we summarize the first learnings from these tests.

The six months test with self-driving shuttles operating on public streets in the LINC just ended, and the project has gained a lot of valuable experience. The three vehicles operated for more than 3000 hours at DTU Campus. The Smartphone sensing platform that enables detailed monitoring of movements around the bus stops and onboard the shuttles proved to function as planned and delivered a lot of useful data about the 665 users that downloaded the LINC app.

When this journal is written, the project team is currently in an intense phase to analyze the data since operation ended November 5th, but some learnings can be made already now:

- the operation of self-driving vehicles is challenging. The technology is still relatively immature, and the semi-public environment with many pedestrians and bikes was sometimes very challenging for the vehicles.
- the vehicles, the sensing platform, the routing and planning, and the users are intertwined and form a very complex system, where small changes in one part impact the other parts.
- in the early planning of the project, the focus was very much on creating an on-demand service. However, learnings from the project show that a well-planned frequency-based service likely will perform better for both users and operators in the context around the planned light rail.
- The project has learned a lot about users and their preferences, and in which situations the shuttles actually provide a useful service. The onboard stewards have been key, both for collecting data and for delivering a good service.

The next step for the project is to compile and communicate the learnings to decision-makers within urban planning. In particular, the smartphone sensing platform will be valuable for planning and delivering many types of shared mobility services. This work will continue also after the project ends on 30th November 2021, and the aim of the project partners is to advance public transport and contribute to sustainable urban planning in the areas around the new Greater Copenhagen Light Rail system.

Project Progress

Achieved during the test

This section is based on interviews with project participants Per Beakgaard (DTU Compute, Soren Jacobsen (Nobina), Hannah Villadsen (Roskilde University Center), and Jeppe Rich (DTU), who are all engaged in the operation end the evaluation of the tests with driverless shuttles at DTU Campus.

The operations on DTU Campus in numbers:

- **3** Vehicles
- more than **6** month long test period (April 19th, 2021 - November 5th, 2021)
- average commercial speed per day around **5** km/h, max speed **15** km/h
- more than **3.000** hours of operation.
- On average around **91%** of the time in AUTO self-driving mode.
- more than **6.000** person-trips
- around **1.000** students, staff, and visitors at DTU joined a users panel to test the shuttles, and share their expectations and experiences
- In total there have been **665** LINC app downloads, whereof 234 are for Android and the rest is for iOS.

In addition to operating the shuttles, the LINC project also released the **smartphone sensing platform** with a connected app for users. The platform uses GPS signals and Bluetooth beacons to sense the movements of buses and users. By doing this, the sensing platform can for example determine which users are onboard the bus and if there are users at the bus stop.

The LINC smartphone app, a Bluetooth beacon at a bus stop, and an illustration of how the beacons are used for determining if a person is on board the bus or at the bus stop

During the tests, data has been collected from the vehicles and the smartphone sensing platform. Data has also been collected in many other ways: **surveys** have been sent out to users, researchers have travelled with the buses to monitor behaviour, and **interviews** and **focus groups** meetings and a **stated preference** (SP) survey have been performed. Researchers have also performed **video analysis** of movements and human-robot interactions at crossings.

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Learnings about operation of AV shuttles

> It is more difficult than one can expect to operate these shuttles

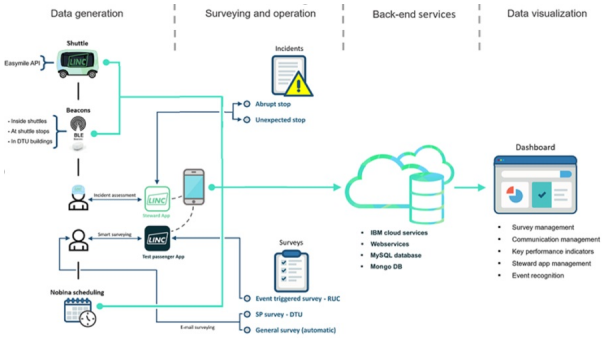
says Soren Jacobsen, Nobina. The project's experience is that self-driving technology is far from mature. Although the vehicle operates up to 91% of the time in autonomous mode, the last 9% of the time includes many challenging situations including misplaced cars and interactions with pedestrians and bikes.

The infrastructure and the environment around the vehicle have a large impact on the operation. Looking at DTU Campus it seems to be a good candidate for testing autonomous driving: it is a semi-public environment, with low traffic speeds and few cars. However, during the tests it turned out that the campus environment is very complex with its many bikes and pedestrians, cars and trucks temporarily parked along the roads and falling autumn leaves from the large trees that interfere with the Lidar sensors on the vehicles.

The vehicles are programmed to follow their digital track and to exactly the same route over and over again. In comparison, human drivers are very good at handling exceptions, e.g. adopting the route if there is a hindrance. Such situations are more challenging for the AV shuttles to handle.

Learnings about the system and the organisation

The vehicles are part of a large system, including the vehicle-to-infrastructure communication, the smartphone sensing platform, the test passenger app, the steward app, and the users and operators. Changes in one part of the system often require changes in other parts. For example, a change in the route impacts many other aspects.



A schematic illustration of the LINC system. A change in one part of the system has impacts on many other parts.

From an organisational view the LINC project has been very complex: many different actors, coming from different backgrounds and carrying different perspectives. Through good spirit and good collaboration the project has achieved the cross-pollination that is crucial to be successful.

Operational costs in LINC have been huge, but we should remember that the technology is still immature. In the longer term, when the technology is mature and the market is ready for adoption, the operational costs are expected to go down and be lower compared to a traditional bus. The transition to a system with self-driving vehicles will likely still require large investments in both technology and in related processes. When the first investments are made, it is expected that marginal costs for adding more vehicles to the system will be relatively low.

Learnings about on-demand mobility services

One key target for the LINC project is to explore the use of driverless shuttles in on-demand service. Due to the delays in getting legal permission to operate the vehicles, the tests had to be limited to a frequency-based service only. Instead, the on-demand service was explored using simulations based on expected demand in Hersted Business park after the opening of the new light rail and testing a number of different service designs.

Surprisingly, the results showed that the frequency-based service outperformed the on-demand service in most cases. In particular, this is true for the case of longer distances (urban sprawl). Based on these findings, the research team draws the conclusion that on-demand services perform best in dense areas while in the relatively sparse areas of Hersted Business park it is likely that a frequency-based service would be the best choice. Further research is needed including a larger area of the future Greater Copenhagen Light Rail to finally conclude on which autonomous service design will be the most appropriate to implement in this specific context.

Learnings about people

The number of returning users has been lower than expected. This means that the service was not adopted in the way that was expected at the beginning of the project. Instead, most users have been curious “tourists”. One important reason is that for most people it was in fact faster and more convenient to walk or bike instead of waiting for the shuttle. However, disabled persons or persons carrying a lot of loads found value in the service.

The shuttles also interact with road users, and pedestrians and bikes experienced that in some situations the shuttles' behavior was very different from manually driven vehicles. This sometimes caused confusion and unexpected situations on the streets.

The steward onboard has been very important during the project. The stewards were supposed to be in the background, to mimic a driverless service. However, during the project, they have actively participated in improving the service offered, supported and informed the users, and sometimes tailored the service to meet the users' needs. One learning is that the role of providing a good and tailored service is very important, and a steward could play an important role there even if the shuttles manage to drive autonomously.

The UIA Challenges and how they are handled

In this section observations related to the UIA challenges are presented, given the current state of the project.

Challenge	Observation
Leadership for innovation Challenge level	The New Light Rail opens up a window for innovative urban planning that the LINC project uses. On a regional level, the involvement of the Greater Copenhagen Light Rail Board of Directors and the Mayor's circle is key, as they sit on future decisions for the first-last mile services. LINC has established communication channels and is currently preparing communication material. However, delivery will be first after the project has ended, because of the short period the project have for reporting after test closure. Moreover, it is a challenge for the project, that the technology matureness level is relatively low. For decision-makers, it will take a good level of abstraction to envision how future autonomous shuttles can transform public transport and the way we design our cities. Nevertheless, on the city level, there is an interest in new mobility solutions as a part of urban planning, and LINC has developed a vision and plan for automated vehicles in transformative urban areas. A video animation depicting the future of public transport is being finalized. This will support the project in the dialogue with decision-makers. The LINC project is also collaborating with other Danish projects on smart cities to create momentum for innovation
Public Procurement Challenge level	When scaling up mobility services, public procurement is both a challenge and an opportunity. New public-private partnerships need to be developed. To scale up it is important to not only consider the incomes from sales of the actual mobility, but also other values such as the increased value of land and increased livability of cities. This is further discussed in the LINC Zoom-in on financial models and in the vision for AV's in urban areas developed in the project.

Integrated cross-departmental working

Challenge level

Multiple departments at the City of Albertslund are engaged in the project, including e.g. infrastructure, industry, and business development. Naturally, the departments have different perspectives and roles in the project, but they all share the same vision that the new Light Rail will enable sustainable mobility and increase the number of citizens and workplaces in the municipality.

The project supports cross-departmental working as it has a cross-disciplinary approach and brings together many aspects, from technology and user perspective to operation and financing models.

Adopting a participative approach

Challenge level

The project has a clear user participative approach and emphasizes first-hand reactions and inputs from users. More than 1000 users have signed up to participate in the trials, the stewards' roles and feedback have been central in the evaluation of the project.

The project has also performed several events. For example, the shuttles visited NEXT Vestskovens Gymnasium to also involve younger students.

Monitoring & Evaluation

Challenge level

The project was well prepared to monitor and collect data from the trials with vehicles. Quantitative and qualitative data have been collected to both evaluate the operation, the user acceptance, and the potential for upscaling. The test phase was prolonged up to six months (new project end date November 2021) to enable data collection and as a mitigation measure due to Covid-19.

Communication with target beneficiaries

Challenge level

There have been several challenges in communication with target beneficiaries: the delay in starting the automated vehicle (AV) tests delayed data collection; the outbreak of covid switched priorities and limited communication channels; the fact that the AV technology was less mature than expected reduced the belief in the belief in the technology.

The project has identified several highly relevant communication channels at different organizations and levels. They have also established a thorough communication plan, produced communication material, and are now also finalizing an animation to communicate their insights and learnings about AVs in sustainable urban planning The project has planned seminars and workshops with politicians at municipal and regional levels, but they will be performed after the closing of the project due to a currently ongoing election.

Upscaling

Challenge level

During the project time, it has become obvious that neither the legislation in Denmark nor the technology, is ready for collective driverless mobility. In addition, with the long lead times in the legislative process, it is not the most recent technology that is actually tested.

At the same time, the smartphone sensing platform that has been developed in the project has a great potential to be used to collect data for transport planning, to understand user movements for service design, to lay a foundation for tailored pricing, and much more. The platform has already been utilized by DTU in Israel for a project called Bikelonger.

What other cities can learn from LINC

The LINC journey is about to end. The project has developed and deployed an innovative mobility service using self-driving vehicles on public streets. A six months-long field test period has now ended, and the project is currently in an intensive phase of analyzing data and producing final insights. While still awaiting the detailed results from the project, two main learnings can already be made.

Start with the problem to solve

Operating self-driving vehicles in a service that users are willing to adopt is a challenge. With the current state of technology, the functionality is too limited to provide a meaningful service to the users if the vehicles are to operate on public streets and among other road users. Given the current state of technology, it is not obvious that self-driving shuttles can provide a meaningful service at a university campus. With the learnings from the LINC project, it would now be relevant to start from the outside in and identify the gaps and the pain points in current collective mobility, and then see how self-driving shuttles could be a part of the solution. The smartphone sensing platform could be a good tool to use.

It is a complex socio-technical system

Providing a mobility service is not only applying advanced technology. It is important to recognize that it is a complex socio-technical system that involves infrastructure & environment, social patterns & users, and technology. For example, the project members realized general weak points in the infrastructure, and they got the opportunity to explore movement patterns and mobility demand through the smartphone app. The fact that the technical test did not deliver the expected service instead leveraged learnings in other fields. One conclusion is: **it is important to perform tests to learn!**

Next steps

Next steps for the LINC project

The project is currently closing the activities and putting together the final results in reports and scientific articles. The project partners will also continue communication with politicians and decision-makers at regional and city levels.
Given the relatively immature technology of the self-driving shuttles in combination with the Danish legislation, which still is very complex and restrictive for autonomous operation, it is not a feasible path to aim for regular

operation of the self-driving vehicles at this point. Instead, Nobina aims at further demonstrations and pilots with the shuttles used in LINC. Such pilots would create valuable knowledge for future deployments. Another, and complementing, path forward is that the project's simulation for one light rail station is deployed to more stations if the Greater Copenhagen Light Rail's Board of Directors finds it meaningful.

At the moment another AV road test is not on the table, as the legal framework in Denmark will be being revised in 2022. The project partners have been invited to contribute with their own experiences. Parts of the project will properly be taken to new projects (for instance Horizon Europe 2021-2027) such as the smartphone sensing platform for demand-responsive services and innovative mobility services. Besides, in the post-project period the following result indicators will be monitored:

1. **Transforming urban planning by providing autonomous mobility**, where the aim is to integrate new collective mobility concepts into the Area Development Plans for at least two of the urban areas along the new Greater Copenhagen Light Rail.
2. **Behavioural change and citizen engagement**, where the aim is to use a participative approach to support passengers to feel confident with the collective autonomous bus service.
3. **Legislative and regulatory framework impact**, where the aim is to use the learnings and experience from the LINC project to reduce legislative and regulatory barriers for the operation of autonomous vehicles in Denmark.
4. **Improved measurements of mobility patterns**, where the aim is to use the smartphone sensing platform developed in the project to improve and enable other mobility services. One example is enabling tickets that are valid during mode changes.

We now know that collective mobility using self-driving vehicles is not a fantasy anymore. Following up on the success of implementing the result indicators will be crucial steps for enhancing further innovation for public transport. It can't be done by a single partner but requires the unity of more from the private-public-academia area. Especially, if we are to harvest the fruits of autonomous technology to the benefit of advancing public transport and sustainable city planning, so urban and traffic planning in the future will become more integrated. and is conceived as a common municipal task.

Urban mobility

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