

DANMARKS TEKNISKE UNIVERSITET



Autonomous Shuttle Bus at DTU

42429 - PROJECT MANAGEMENT

GROUP 61

NICOLAI DYNWEBER BRUHN s153981

Nicolai Bruhn

GUSTAV NØRBJERG s194145

Gustav

Hasse Bülow Pedersen s194153

Hasse Bülow Pedersen

Lukáš Málek s212074

Málek

August 2020
DTU Management
Technical university of Denmark

1 Executive summary

This report investigates the LINC project at DTU. The LINC project is a project that focuses on autonomous vehicles and their interactions with a dynamic environment on Lyngby campus, DTU.

Approximately 100 people have been engaged in the project, though not all equally. The main groups of people behind this project are: Albertslund municipality, DTU, Nobina and Gate21.

The project started in March 2018, but the preliminary started in 2017. The project was supposed to end in March 2021 but has gotten delayed for 9 months due to the legislation process and Covid-19.

This study is made as part of the course 42429 Project Management and will dive into the challenges and difficulties one will encounter doing an innovative project. The report has four focus points in which the project has been analyzed: purpose, people, complexity, and uncertainty.

The purpose section is analyzed by looking at the: output, outcome and benefits, goal hierarchy and the iron triangle.

The people section is looking at the perspective of people and stakeholders using a stakeholder matrix, how they communicate and manage interest and influence.

The complexity section is looking at the scheduling, resources and time estimations of the project and going into detail with how the work is organized.

The uncertainty is investigating the risk management and uncertainties for the project and how they were handled.

The goal of the project was initially to support the upcoming light rail on DTU campus and gain more insight and experience within this field of technology. Due to the delays of the project and a decrease in motivation, the goal of the project changed more towards a research project within the technology used for autonomous vehicles.

According to the project manager, there was little they could do with the legislation and Covid-19, and could therefore not have prevented the delays the project has experienced.

Looking at the project from an overall perspective, it is concluded to be a success. Even though the project has met delays during its lifespan. Delays like that the legislative issue could have been predicted, but Covid-19 was an unpredictable.

The people behind the project have gained experience on how autonomous vehicles behave in a dynamic environment, and how people are interacting with the technology. They have also collected data that can be used in further studies on how to incorporate the technology at other places. This can be used as a foundation for further use of autonomous vehicles in Denmark.

Contents

1	Executive summary	1
2	Methodology	1
3	Introduction	2
4	Purpose	3
4.1	Output, Outcome, and Benefits	3
4.2	Scope	3
4.3	Life Cycle	4
4.4	Success Criteria	5
4.4.1	Iron Triangle	5
4.5	Project Success	6
4.6	Reflection and Recommendation	6
5	People	7
5.1	Stakeholders	7
5.1.1	Managing, Interest, and Influence	8
5.2	Communication	10
5.2.1	Meetings	10
5.2.2	Conflicts	10
5.3	Reflection and Recommendation	11
6	Complexity	12
6.1	Schedule	12
6.1.1	Workflow	13
6.2	Resources	13
6.3	Time Estimation	13
6.3.1	Cost Estimation	14
6.4	Reflection and Recommendation	14
7	Uncertainty	16
7.1	Risk management	16
7.1.1	Threat and Opportunity	18
7.2	Scope Creep	19
7.3	Reflection and Recommendations	19
A	Gantt Chart	21

List of Figures

1	Timeline for the LINC project.	2
2	Goal hierarchy showing how and why the different stakeholders are involved	4
3	The Iron triangle with cost and quality as priority	5
4	Stakeholders for the LINC project	8
5	Stakeholder matrix showing the Power vs interest.	9
6	An example of how the Stage-Gate model could have been used on the project	14
7	Fishbone Diagram	17
8	Double Probability Matrix	18
9	GANTT chart for work-packages 4 & 5 part 1	21
10	GANTT chart for work-packages 4 & 5 part 2	22

2 Methodology

In the beginning, the research was based on secondary data. In order to ask appropriate questions in the upcoming interview, it was crucial to understand the project's background. The interview was the fundamental source of this report and the only source of primary data. Every source used was qualitative research.

The **LINC website** was used while searching for basic information. The data is reliable, since it is the official website.

UIA journals[1][2] were a valuable source with more in-depth knowledge. It is a European Regional Development Fund and a main funder of the project. The journals contain information about issues and challenges within the project, and what they have focused on since the last update and where their focus would be for the next 6-12 months. These journals gave a good insight into the challenges throughout the project and what sub-goals they were working on.

Interviews were the most suitable approach to answer our questions about the project. The selection of participants had two factors. Firstly, the interview had to be conducted in less than two weeks. Secondly, we were looking for someone who could answer our questions related to project management. Therefore Kenneth Jørgensen was chosen, who is the overall project manager from Gate 21, and Jens Dahlstrøm, as he is responsible for the project at the DTU. We had three interviews in total. Two with Jens and one with Kenneth. Each interview lasted about an hour.

The first interview was with Jens at the DTU Library. After the brief introduction about the project, the interview focused on the Purpose and People perspective. Questions were prepared in advance and were answered very straightforward. The second interview with Jens was held online via Microsoft Teams, and the question followed the Uncertainty and Complexity perspective. Jens could not provide all the necessary answers to our questions, as he is not the overall project manager. Though, he provided key insights and a better understanding. This allowed us to better prepare for our third interview with Kenneth on Microsoft Teams. The questions were prepared to clarify some statements from Jens, and to answer the questions which he could not provide a thorough answer to. The interviewee answers were complex and across multiple aspects. Though, during this interview, there was not enough time to ask all prepared questions. Kenneth was harder to interview as he would take long detours. On the first question, he ended up talking for 20 minutes. A second interview with Kenneth was not possible as he had to cancel the first scheduled interview because they had new issues within the LINC project.

Every interview was recorded and transcribed. The questions for the discussion were mostly following the guideline prepared in advance with minor changes to make them fit the project. The answers were used to analyze and better understand the project.

Documents about the project were received after the interview. Jens provided the list of work packages about the shuttle testing approval at DTU Campus, and Kenneth shared the presentation about Risk Management and KPIs. Both are also considered high-quality, reliable sources since they are from the project managers themselves.

The purpose of the project and the overall success was answered during the interviews. All the information received during the discussion were interconnected, and no discrepancies were found. Biases were handled by multiple people contributing to the question preparation and interviewing two people involved in the project. The findings in this report are reliable, as information is crosschecked between Jens and Kenneth, and used published information in the UIA journals.

3 Introduction

LINC is one of the largest collaborations in Denmark that tests autonomous bus shuttles. After years of testing, they have deployed its buses onto the DTU campus streets to test how they interact with other cars, bicycles, and people. Currently, they are demonstrating the autonomous bus shuttles in two other locations, at Albertslund and Hosted Industripark.

The Danish government made new regulations on the 1st of July 2017 that allowed autonomous vehicles to drive on the roads at a maximum speed of 18 km/h [3]. This change opened new opportunities in the market for autonomous vehicles. Currently, the LINC project is not the first shuttle bus driving on danish roads. In Aalborg, the company Navya have their shuttle bus available to the public[4].

The main reason for starting the project back in 2017 was the vision of the DTU Smart campus. It takes a long time to walk across campus, and it was easier to get permission on DTU since the roads are partially closed off. The LINC partnership was created to gain experience within autonomous bus shuttles, their operation limits, and their influence on the people who use them. Data gathered from the project is meant to be used for further development within autonomous systems in urban areas. The project also aims to complement the light rail's 29 stations by helping people reach the last mile of their trip to their destination.

Multiple partners are involved in the project across industries, institutes, and municipals institutions. About 35 people are actively contributing to the project. However, more people are involved in the project on a smaller scale. These people work for the different stakeholders such as the Municipality of Albertslund, Municipality of Gladsaxe, Nobina Danmark A/S, IBM Danmark ApS, The Technical University of Denmark, Roskilde University, and Gate 21 [5]. The partner Nobina has a commercial interest in the project, and they are the largest public transport operator in the Nordic regions.

The project is financed through the EU program Urban Innovative Actions (UIA), which granted the project with 25 million DKK [6]. The grant is not immediately paid out, instead it is paid in phases. The phases depend on the work-packages defined for the project. Certain work-packages are required to be part of the project plan. Throughout the project, a percentage of the grant is paid after financial audits are performed, and project reports are accepted by the comity[6]. Initially, the project was due by spring 2019, but significant delays were experienced. The leading cause of the delays was the slow legislation process of approving the chosen shuttle to drive on DTU's roads. Secondly, not enough testing data were gathered on time due to the global pandemic. The timeline for the project is in figure 1.

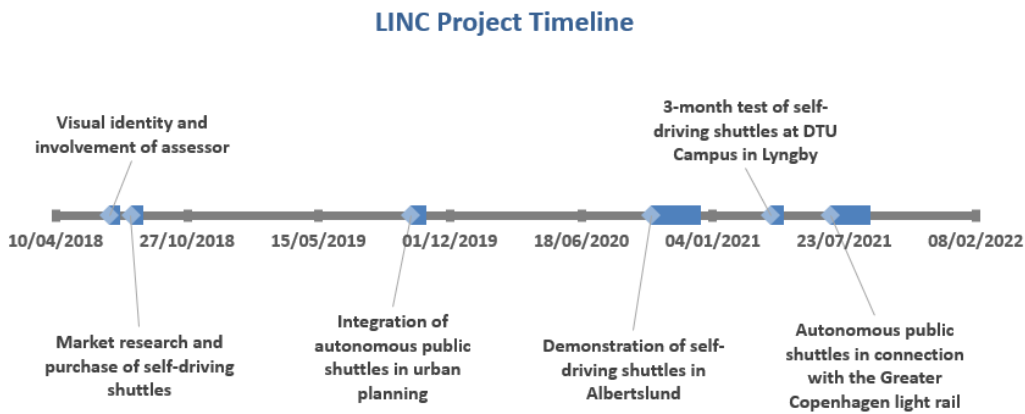


Figure 1: Timeline for the LINC project.

4 Purpose

The purpose is the aspect where the project is connected with the "why?" and "what?". "What" is one of the foundations projects are builds on, and it is a shared understanding among the stakeholders. This understanding is necessary in order to achieve a successful project. "Why" is the reason the individual stakeholders are participating in the project.

This project started due to the change of the legislation surrounding autonomous vehicles mentioned in section 3. According to one of the project managers from DTU, UIA supported the project based on the following:

"For Urban Innovative Actions, it was more important for them to have a kind of a bold project with the license to fail."

— **Jens Dahlstrøm**, Operations manager LINC, DTU

The LINC project is mainly a research project with the purpose of having the testing ground to mature the technology. The project's purpose depends on the stakeholder's view. Nobina's main goal is to gain experience and knowledge about autonomous bus shuttles, and how they interact in a dynamic environment with unforeseen obstacles. Nobina wants to apply this knowledge for commercial use, whereas for DTU it is a research project. The purpose analysis is conducted from the perspective of DTU.

4.1 Output, Outcome, and Benefits

The LINC project has several outputs, all depending on the different stakeholders involved in the project. Using the Prince2 definition, the output, outcome, and benefits can be seen below in table 1, which is based on the view of DTU.

Output	Outcome	Benefits
Autonomous buses on DTU	<ul style="list-style-type: none">• Easy transport across campus.	<ul style="list-style-type: none">• Reduced CO2 emission from cars.• Safer transportation on the roads.• Fewer parking requirement.• More efficient use of the road.• More flexibility for commuters.
Gained knowledge on DTU	<ul style="list-style-type: none">• Expertise in autonomous systems• Expertise in creating of sensor networks	<ul style="list-style-type: none">• International recognition

Table 1: Prince2 definitions for DTU's perspective

4.2 Scope

The purpose of this project can be divided into smaller parts since it has multiple scopes. Seen from the perspective of DTU, the LINC project will accommodate the upcoming light rail that is being built on DTU. Moreover, it will use the infrastructure on campus to test new technologies and collect data. This follows one of DTU's goals, smart campus.

"Back in 2017, we really had a vision on DTU. The vision was called Smart Campus, and the purpose was that we could use the campus infrastructure to test new technologies."

— **Jens Dahlstrøm**, Operations manager LINC, DTU

Looking at the LINC project from an overall perspective, it is a goal oriented project, with the project divided into seven different work-packages. Throughout the project, there has always been a lot of uncertainties, since

it is an innovative project. The LINC project has been fast and vigorous when dealing with new uncertainties and adapted quickly by changing the scope based on the challenges that has risen. One key example is Covid-19, which resulted in fewer test passenger. They quickly funneled more money into a different work package, so they could focus more on research and thereby avoid any further delays and keep up with the goal. This can be summarized in the figure below, showing the different scopes of the stakeholders and what they are achieving from the project.

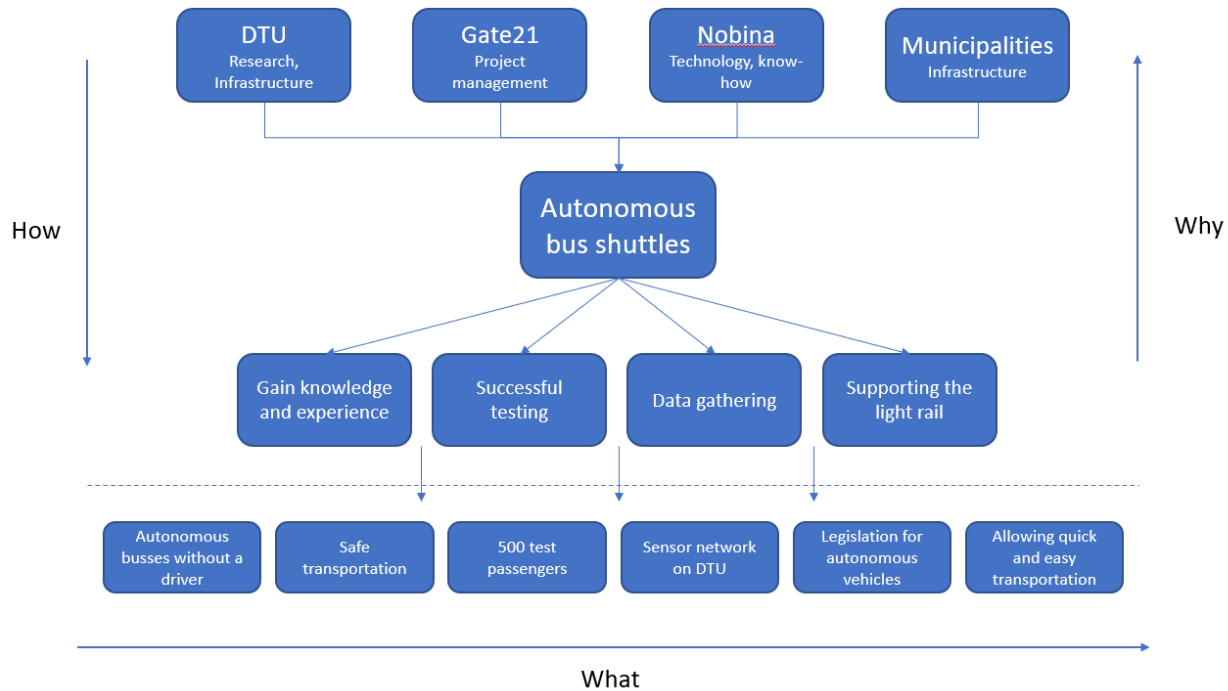


Figure 2: Goal hierarchy showing how and why the different stakeholders are involved

4.3 Life Cycle

The initiation stage started in 2017 after the Danish government agreed on autonomous vehicles driving on the road at the maximum speed of 18 km/h. The planning phase lasted longer than expected, caused by choice of a bus supplier:

“We had Easy Mile, and then we had Navya. Navya had the advantage of having been type-approved in Denmark. (...) We did not have that for the Easy Mile shuttle, which we chose.”

— **Jens Dahlstrøm**, Operations manager LINC, DTU

Testing self-driving shuttle buses require a specific vehicle’s approval with the Danish Transport Authority and an external risk assessor, in this case Atkins. Obtaining a permit for a test drive of the shuttle bus involves a time-consuming political process.[5] The initial estimation for getting these approvals was nine months, a year at worst. Since the process is sensitive to the calling of elections, Covid-19 or the shuttle busses not living up to the standard, the application process took 2.5 years, resulting in shorter testing periods and opportunities to gather experiences from the test drivers.

The execution started on April 2021, when self-driving shuttles were finally approved for test drives at DTU Campus. However, due to the coronavirus spreading across the globe, researchers were challenged by the fact that most students were taught virtually. The project is coming to an end in October 2021.

4.4 Success Criteria

For the project to be perceived as successful, then it must fulfil some success criteria. The primary criteria of success for the project is to transport at least 500 passengers and get the infrastructure ready for use.

4.4.1 Iron Triangle

The iron triangle is a common tool to measure a project's success in practice. However, it does not take into consideration the safety or benefits. The three constraints in the iron triangle are Time, Cost and Quality.

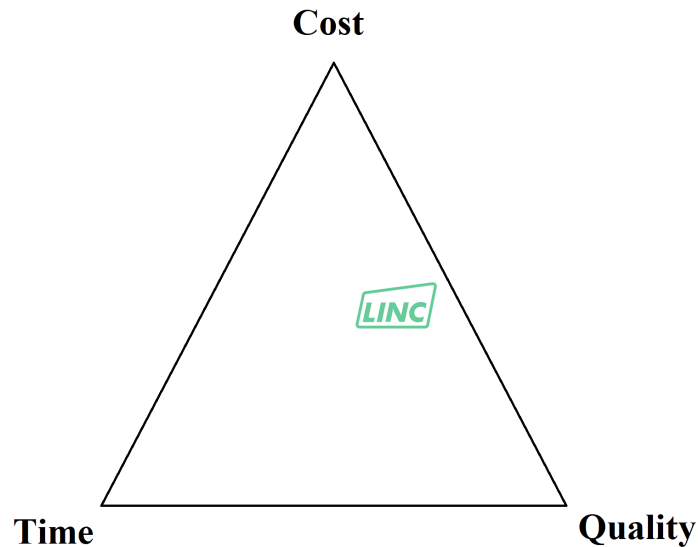


Figure 3: The Iron triangle with cost and quality as priority

Cost is one of the requirement for the success of the project. The project has been granted 25 million DKK from UIA and will not be granted more if the project goes over budget. As this grant is about 80% of the total budget, the project has to be managed cost-efficiently to be finished.

Quality is the second one of the main criteria. Poor quality of the product means that the passenger's safety would be in danger. Any harm or injuries to passengers would result in the project being considered a failure, and the public image of the autonomous shuttle could be damaged. This is due to autonomous vehicles still being a relative new technology, so accidents involving these vehicles would get more publicity than a normal car accident.

Time had the lowest priority in the project. Therefore, the deadlines and time-plans are dictated by the cost and quality constraints. UIA gave the project extensions because of the Covid-19 situation.

4.5 Project Success

According to the success criteria, the project fulfilled most of them by transporting over 800 of the planned 500 test drivers. Secondly, it set up the infrastructure for future shuttles at DTU. However, for Jens Dahlstrøm, Operational manager LINC, it was not that big of a success they had hoped for due to delays and Covid, but overall he commented on this:

“I think things that are in our control, we have really met the criteria in the dialogue with grant giver changed the criteria to something that is more current.”

— **Jens Dahlstrøm**, Operations manager LINC, DTU

Secondly, some major issues are the fact that service is not good enough. The shuttle is too slow and too difficult to use, as mentioned by Jens.

For the UIA and DTU, it was a research project to test autonomous vehicles with limited funding. From their point of view, the project would be considered successful despite being delayed, which caused some work-packages to change.

4.6 Reflection and Recommendation

The LINC project, as seen from the perspective of the purpose, is considered a success because the team adapted the goals even after unexpected and unpredictable events. At each phase, they agreed with other stakeholders on the current purpose, goals and the most important criteria, and they fulfilled them. They managed to bring new innovative technology to DTU. This resulted in DTU becoming the first university in Denmark with its own automatic shuttle system, and they have gained tremendous knowledge and inside into the automation process. The owners and project leaders Jens Dahlstrøm and Kenneth Jørgensen have shown they have a big understanding of what they are trying to achieve and why they are doing so. From this, they are showing a clear purpose why this project exists.

Though the team could have been more clear on how they are going to achieve it. They could have prioritized time a bit more compared to cost and quality. This would have prevented project delays and helped them pick an alternative provider for the shuttle. One option would be the Navya shuttle that was already certified to drive on danish roads. From this, it feels like the team did not know exactly how they were going to achieve success, and instead figured it out during the project.

5 People

Without people there are no projects, people are the essence of projects. One cannot successfully build a rocket if all the people behind it are fishermen.

Analyzing the people aspect of a project can be divided into three categories: people as individuals, as a team and as an organization. We will in our analysis focus on the people as an organization, the stakeholders and how they communicate.

5.1 Stakeholders

The stakeholders consist of five different groups: Users, Municipalities, Researchers, Service suppliers and the employers, business owners and facility owners. [7]

All these stakeholders have an important role in making the project successful.

The users	The users are a crucial part of the project since they give the necessary data that this project is built upon. This has been done through an app that will collect the data.
The municipalities	The municipalities have high interest in supporting the development of this technology, as they will use it to modernize its cities and make it more attractive to live in them.
The researchers	The researchers help with processing the data and gain valuable information about the operations of autonomous vehicles. This is a major part of the project, and the knowledge can be applied to other projects in the future.
The service suppliers	The service suppliers deliver the bus shuttles, through EasyMile, needed for the project together with maintenance, upkeep and operation done by Nobina.
The employers, business owners and facility owners	These are the people who grant approval of testing grounds for the project.

One of the big tests for a project is not when things are going well, but when things do not go the way as expected. It is therefore very important for a project manager to keep in contact with the stakeholders to see if they are satisfied or not, or have any frustrations. This is something the project manager of LINC has done well, since there have only been minor frustrations due to delays, but no major fall-outs.

“People has been very constructive, and they have been very supporting. And I believe it’s because that its very obvious that we have there’s been some other frames that we couldn’t control, and you want to be in control in a project, but you need to at some point, you need to say, okay, I’m not in charge of that. I’m not capable of controlling the slate of framework.”

— **Kenneth Jørgensen**, Senior Project manager LINC, Gate 21

All the stakeholders in the project can be seen in a stakeholder classification in figure 4.

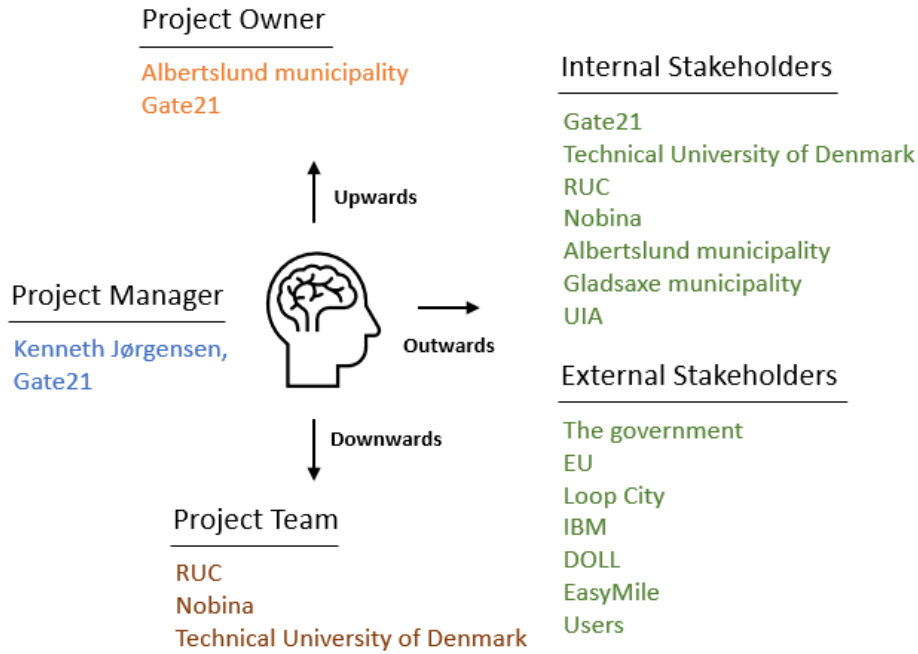


Figure 4: Stakeholders for the LINC project

The stakeholders placed in the upwards section are the project owners, who control the project. The stakeholders in the sideways section are all the stakeholders of the project. The internal stakeholders have an interest in the finished product, whereas external stakeholders have not. The stakeholders in the downwards section is the team working on the project.

5.1.1 Managing, Interest, and Influence

Maintaining communication with stakeholders and checking whether they are satisfied is a good practice. The reason for this is to make sure the project is proceeding exactly as expected by all stakeholders.

Managing stakeholder expectations was something Kenneth Jørgensen, the project manager, did by communicating weekly with them about progress:

“[A] good thing is that you need to be in contact with the project partners, if not on a daily basis, and then on a weekly basis and just call them and say how things are going, need any help or so on. That maybe sounds like basic things to do, but it’s very crucial to you have hands on where you have your project partners and are they satisfied or not.”

— **Kenneth Jørgensen**, Senior Project manager LINC, Gate 21

A way of keeping track on how to handle stakeholders is through a stakeholder matrix, which shows the different stakeholders influence and interest in the project.

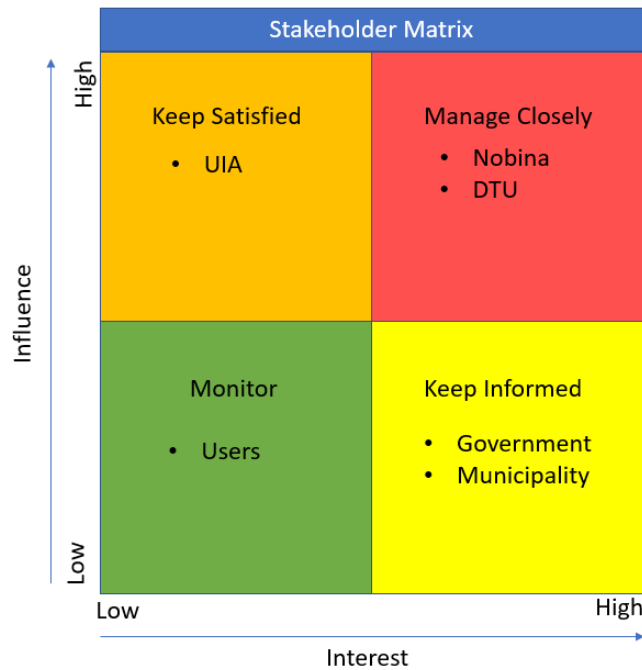


Figure 5: Stakeholder matrix showing the Power vs interest.

From this it can be seen the UIA need to be **kept satisfied** since they are the one funding the majority of the project. This happens through the delivery of completed work packages.

DTU and Nobina needs to be **managed closely**. As DTU facilitates the project and incorporates it into the Smart Campus, the project manager needs to manage these closely. Nobina is closely managed because they are the suppliers and own and operate the shuttles.

The government and municipalities needs to be **kept informed** during the project. The government since they are creating the legislation for autonomous vehicles and granting permission for the different shuttle types to drive on the road. Whereas the municipalities need it since they are implementing the technology. For the **monitor** sections, the users of the shuttles were monitored through surveys and an app.

5.2 Communication

A key aspect to a successful project is communication. This is also the case for the LINC project, as many stakeholders are actively engaged in the project. Initially the team went through the different phases of forming, storming, norming, performing, and adjourning.

“[W]e started out with quite frequent meetings for the entire team to have. (...) I believe in that phase, it was also very chaotic. I think you have the storming, norming forming, performing phases, and you can definitely see some of those meetings as storming, because you had a lot of opinions. You had kind of people having different expectations about the project going into the project, and now we really needed to align on...”

— **Jens Dahlstrøm**, Operations manager LINC, DTU

Forming: The forming stage can initially be seen in the project, with partners playing with closed cards. This was something they had to overcome as e.g. Nobina would like to not create a lean approval process for competitors.

“So the transparency in that regard has been really important. (...) In the beginning, [Nobina] were kind of, you know, held their cards close because it was also kind of a company secret. But it was kind of if you also have other companies who wants to provide a ton of mobility in Denmark. So if you kind of create a lean process for getting these approvals, you would have a competitive advantage. ”

— **Jens Dahlstrøm**, Operations manager LINC, DTU

Storming: As the meetings went on, they had different views of what were the goal and expectations for the project and needed to align this.

Norming: Expectations got aligned and based on the storming the work packages were created and distributed between partners. Each work package had an assigned budget.

Performing: The partners working on their work packages, e.g. Nobina having to acquire the shuttles.

Adjourning: The project is currently in the adjourning stage and is wrapping up.

5.2.1 Meetings

All the partners were part of the initial meetings. After a meeting, the minutes were distributed, and status mails were sent out to all parties. As the project went on, the communication form changed. The big meetings were switched out with smaller group meetings held by the different work package managers. As the project progressed, the meetings were narrowed down to the key people. Initially it was managed very democratically where everyone had a saying in the direction the project was going. Later the meetings were more centralized and just reading the minutes would suffice instead of attending.

“[Later] written minutes would suffice where in the beginning of the project, you would need to attend the meeting and kind of get the sense of the room.”

— **Jens Dahlstrøm**, Operations manager LINC, DTU

5.2.2 Conflicts

Since the project was run as a distributed organization with many leaders, it was effective, but it was tough to make the final decision and avoid conflicts, and trade-offs. Especially during the two and a half years of approval phase, the key to keep people motivated and reduce conflicts was celebrating small milestones.

Nobina was responsible for the bus approval, which was estimated to be nine months. Handling the fact that they were waiting for 2.5 years was challenging for everyone. Losing even a month in such a competitive

environment has consequences. The goals changed from testing with real traffic to closed roads inside the campus.

Nevertheless, there have been no big conflicts, though the reshuffling of budget was a possible conflict that had to be handled meticulously.

“that’s always tricky that some partners need to let go of some of their budget for us to do more work. (...) But I think in the end, we all have the end goal of having a successful project.”

— **Jens Dahlstrøm**, Operations manager LINC, DTU

Transparency and the vision of a successful project had been essential to avoid project failure. The openness between the stakeholders had also increased throughout the project. In the beginning, the companies did not want to share their know-how, and they kept company secrets. However, towards the middle and end of the process, the books were open for everyone to see.

“In the beginning, they were kind of, you know, help their cards close because it was also kind of a company secret.”

— **Jens Dahlstrøm**, Operations manager LINC, DTU

5.3 Reflection and Recommendation

Throughout the project, one of the important focuses have been stakeholder management because of the project suffering many delays. The project manager Kenneth have done a good job managing the stakeholders and have avoided any major conflicts. Even with topics such as budget reshuffling and delays, he has managed to keep stakeholders satisfied by always being in close dialog with all stakeholders.

One of the key aspects of working together is trust. At the start of the project, Nobina held their cards close to the chest, which resulted in some uncertainty about the goal of the project. The limited trust at the beginning of the project could have damaged some of the important decisions that would have paved the way for the goals.

Another very important aspect is communication. As the project progressed, Jens Dahlstrøm, which is one of the work-package leaders, stopped participating in all the project management meetings. This could have resulted in alignment issues and should probably have been avoided.

6 Complexity

The complexity of a project differs depending on what the project is, but overall it can be divided into three different categories: separating, integrating, and adapting. This however is a bit different for LINC, since it is an innovative project. This implies that most of the things they are working with is in a new territory that have never been explored before. This creates even more complexity for the project. New legislation, new technology, Corona - this aspect will be analyzed and discussed in this section.

6.1 Schedule

A project's schedule is important because it separates each work package and makes the work more manageable. GANTT charts were used throughout this project to plan around time-critical periods. This helped visualize the planning and set deadlines. An example of a GANTT chart used by DTU's project manager can be found in appendix A.

“I don't think we've made a GANTT chart for the entire project as a whole, but rather, in the periods where time was really critical”

— **Jens Dahlstrøm**, Operations manager LINC, DTU

Having an integrated GANTT for the whole of the project was not possible due to the project being innovative and constantly changing. The practice of creating GANTT charts only during time-critical periods prevented wasting resources when they lacked the knowledge needed to plan ahead. As the project progressed, they learned more about the project, which helped them to better plan time-critical periods.

In order to speed up a project, it is beneficial to do non-dependent work packages concurrently. The GANTT chart in the appendix A shows this parallel work as well.

“So we have been working with GANTT charts and time tables in order to kind of keep track of what's the critical path in achieving our milestones.”

— **Jens Dahlstrøm**, Operations manager LINC, DTU

Another way the project has been scheduled is through the yearly journals sent to UIA. From low to high priority, these journals highlight which issues should be addressed in the next six to twelve months. The first journal focused more on technical readiness than legislative readiness. This was because Nobina already had experience getting approvals in Sweden and Norway.[1]

However, their focus changed in their latest journal, in which they started focusing more on legislative readiness, financial sustainability, and up-scaling. This change of focus is due to the project being nearing completion and the legislative readiness being more challenging than expected. Financial sustainability and up-scaling both rely on the legislative part of the process.[2]

Considering that the project has mainly been delayed by the legislative part, this could have been partially avoided if Nobina had placed legislation readiness at the top of its priority list.

6.1.1 Workflow

The LINC project has been very iterative, but has always been in a loop since they constantly needed to make changes to the plan. This is due to it being an innovative project where you go from stone-to-stone. Not like a traditional project, where you make all the important decisions in the beginning of the project. This kind of project can be compared to test of software - the code and fix model. Your method of progress is test, test and test.

“[I]t is more day to day planning, and iterative planning that we will rely on.”

— **Kenneth Jørgensen**, Senior Project manager LINC, Gate 21

The LINC project has used an adaptive/agile approach of workflow, which is perfect for an innovative project with complex problems and unknown solutions.

6.2 Resources

For the LINC project, resources were very limited, and the budget was fixed to the 25 million DKK from the UIA. For a project to be granted money from the UIA, they have to do a proposed work plan and a budget. Based on the estimated costs from their delivered budget, the project can be financed up to 80% of the costs by UIA. Secondly, at least 20% must come from partners own resource or other sources not related to EU funding. This can be seen from the UIA guidance[8]. For the project, two critical activities can be seen as resource dependent and procedure dependent.

Acquiring the shuttles is resource dependent and could be sped up by buying shuttles from both EasyMile and Navya or by paying a higher cost for the shuttle.

The approval of test sides for driving the bus is mainly procedure dependent, as it is regulation dependent. This requires different government entities have to approve the process. Though this can also be seen as resource dependent as this process could be sped up by having more people working on it. This might seem a bit weird that a regulation dependent could have been sped up having more people.

The key issue is the approval process is so complex, that they could not manage two applications for different locations at the same time.

“Originally we had two tests beds, one at DTU and the second one in Hersted Industrial Park in Albertslund. And what we soon came to realise in the project was that we couldn't manage two applications”

— **Kenneth Jørgensen**, Senior Project manager LINC, Gate 21

Overall, the project is cost restricted by having a fixed budget and human resource restricted.

6.3 Time Estimation

Time estimation has been a huge issue for the project. The project has been delayed by several months. For the project, time has mainly been estimated using *Expert Judgement* as mentioned by the DTU project manager.

“[I]t's always difficult to do it precisely, but [time estimate] is based on the experience of the senior researchers who are in the project.”

— **Jens Dahlstrøm**, Operations manager LINC, DTU

This method did not work very well. Originally they expected the approval process to take 9 months based on Nobina's experience from getting the EasyMile shuttle approved in Sweden. In reality it took longer. The

time estimating process has not been easy because of the scope changing all time, as mentioned by the overall project manager, Kenneth.

“We do changes all the time and we learn all the time. And there’s no kind of ending point.”

— **Kenneth Jørgensen**, Senior Project manager LINC, Gate 21

6.3.1 Cost Estimation

The project was innovative and not something that had been done in Denmark. This meant that standard estimation could not be used. Instead, they relied on *Expert Judgement* cost estimation by contacting other projects around Europe to e.g. figure out the pricing of the shuttles.

“[Cost] is something that when you build the project, of course, you try to inquire with other who have experiences in this.”

— **Kenneth Jørgensen**, Senior Project manager LINC, Gate 21

Another possible tool, they could have used, was *Reserve Analysis*. Reserve analysis key focus is to take uncertainties into account for cost estimation, thereby allocating a buffer for each work package. This could help the project, as uncertainty has been very high. With an extra buffer, the project might have been able to avoid shuffling money around.

“[W]e have done a lot of budget changes as well. So you transfer budget from one work package to another. You know, you have a total budget, can’t exceed that total budget”

— **Kenneth Jørgensen**, Senior Project manager LINC, Gate 21

6.4 Reflection and Recommendation

In this project, the Stage-Gate model could have been another great tool for scheduling. Upon completion of each of the following stages: Preliminary assessment, Definition, Development, Validation, and Commercialization, it must go through gates. These gates determine if the project manager should continue, terminate, recycle, or defer making their decision. This helps them decide whether the project is still worthwhile, or if they should kill it and save resources whenever possible.

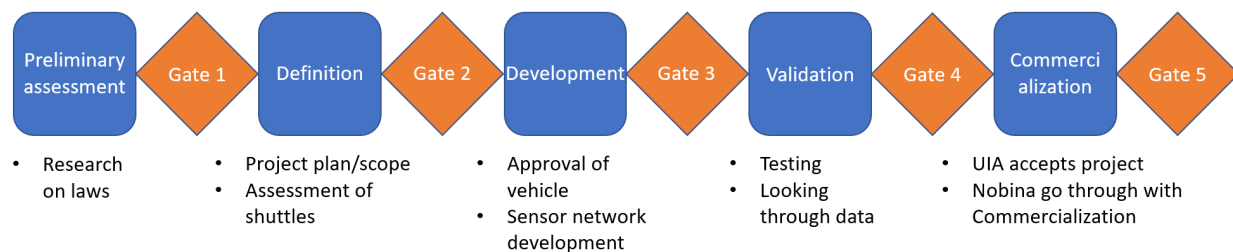


Figure 6: An example of how the Stage-Gate model could have been used on the project

The Stage-Gate is a predictive model, so it can be difficult to establish it at the start of the project, but it might help the project determine its next step. Further, it can include agile workflow for innovative projects, a process known as Agile-Stage-Gate.

This model could have been used to determine if the gate criteria have been met and if the project should be put down or continue. For example, in **Gate 1** they could have stayed in the **Preliminary assessment** stage to do more research on the laws, since this was one of the bigger problems in the project.

Doing the later gates it might also have been difficult to put down the project since the grant would then have to be paid back and Nobina already have bought the Vehicles early on. This could lead to the **Gates with no teeth** where projects rarely get put down due to lack of decision-making or almost non-existent gates.

As for the estimation, the project is an innovative project and contains a lot of new technologies that have not been worked with in Denmark. Kenneth Jørgensen mainly relied on expert judgement from projects outside Denmark to estimate e.g. cost. A suggestion would be to combine it with reserve analysis, thereby the budget allocation could better be estimated, as it is a risk based project. Thus, they might have avoided having to shuffle the budget around between work packages.

From the interview, it also seems that Kenneth Jørgensen was very biased in the way they picked the shuttle producer, as Nobina had already worked with the EasyMile shuttle in Sweden. The Navya shuttle was more expensive, but it had already been approved in other places in Denmark, thereby he added unnecessary uncertainty and made the schedule very erratic in nature.

7 Uncertainty

Uncertainty is a project manager’s worst nightmare. No matter how much you plan, you need to leave some buffer time for the things you cannot anticipate. This happened for the LINC project as well. One of the major uncertainties was of course the world pandemic, which caused delays due to the project was dependent on people. Other uncertainties also caused major delays.

Normally in a project all the important decisions has to be made in the beginning of the project and all the available knowledge and information is only available at the end[9]. However, this is not the case for project LINC. Due to uncertainties, we will discuss in this section, a lot of the important decisions had to be made at the end of the project due to changes of the goal.

7.1 Risk management

In complex projects, unexpected risks cannot be fully eliminated by up-front planning. Since the project was one of the first involving self-driving shuttles in Denmark. There was a lot of things to consider in the risk management, which were hard to predict as you could not rely on experiences. To control these risks, many tools and theories as Fishbone diagram were used during the project. Some of the most critical risks experienced through the project can be seen in table 2.

System development	Unknown-known	The system development for data collection was delayed, resulting in further changes in project across work-packages.
Incidents with vehicles	Known-unknown	Any accident can cause that the state regulators will slow down the approval of self-driving vehicles on public roads.
Partner drop out	Known-unknown	In the first year the partner called LOOP CITY dropped out. This decision affected the project’s vision on having a first/last mile autonomous service connected to the light.
Technological obstacles	Unknown-known	The technology proved to be much less mature than expected, which resulted in testing at a lower autonomous level.
Unproven legal framework	Unknown-known	The Danish legal framework has proven to be very complex in comparison with other countries and the approval took more time than expected.
Covid-19	Unknown-unknown	The global crisis significantly influenced the public transport sector. This resulted in fewer autonomous demonstrations.

Table 2: Cause and effect of different risks

Not all of these risks could be predicted, especially Covid-19. The huge impact of legislation hurdles were not expected.

“[W]e started with the application work to the authorities, and we get to realise got to realise that this is far more risky than we thought.”

— **Kenneth Jørgensen**, Senior Project manager LINC, Gate 21

One of the things they used during the project was a Fishbone diagram to identify the causes of the legal hurdle. A Fishbone diagram provides a structured approach to identifying potential causes for problems, by grouping them in themes. The figure shows how all work-packages are dependent on the legal permission. The project could not move to other phases without the legal approve. Thereby, the project was held up for years because of the legal issues.

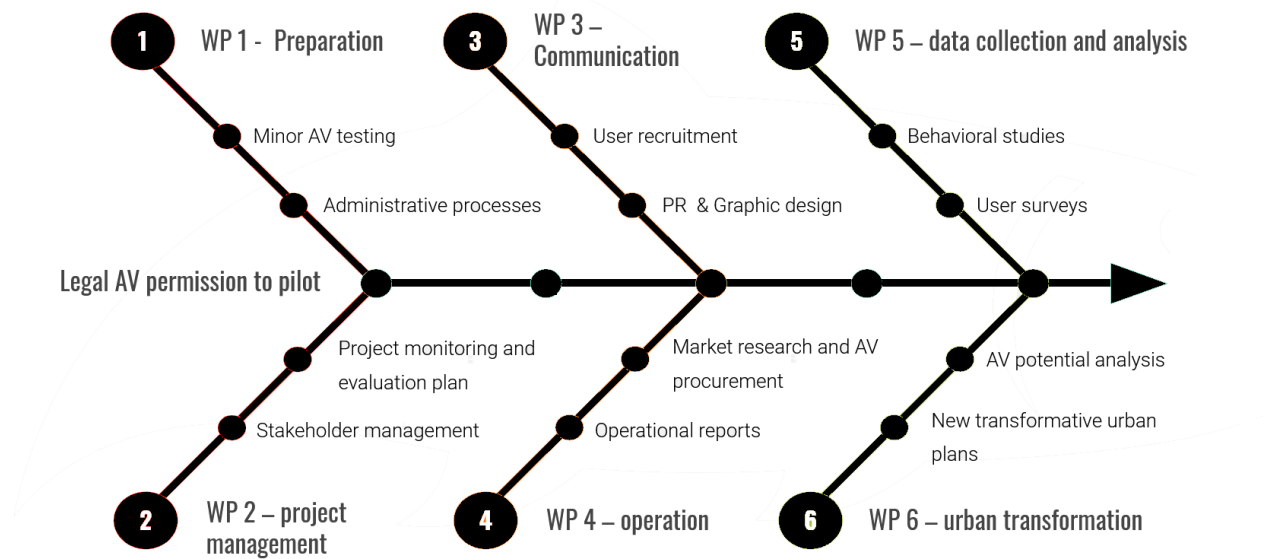


Figure 7: Fishbone Diagram

The risk management was also a key factor to the project ending up as a success. This was not performed traditionally and instead was a weekly activity.

“We started to do risk management on a weekly basis. (...) that has been that has been crucial for the project.”

— **Kenneth Jørgensen**, Senior Project manager LINC, Gate 21

7.1.1 Threat and Opportunity

Not all the risk has a negative consequence, where some risks can also be opportunities. For example, in this case Covid-19 resulted in many threats, but also provided an opportunity to extend the project duration with approval from UIA. The project manager successfully reacted to the most important threats and opportunities with the high risk or high benefits for the project. The decision was accurate, and the scope was reoriented to the actual situation, which highly contributed to the overall project success, at least from the DTU perspective. The risks can be shown in the following double probability matrix.

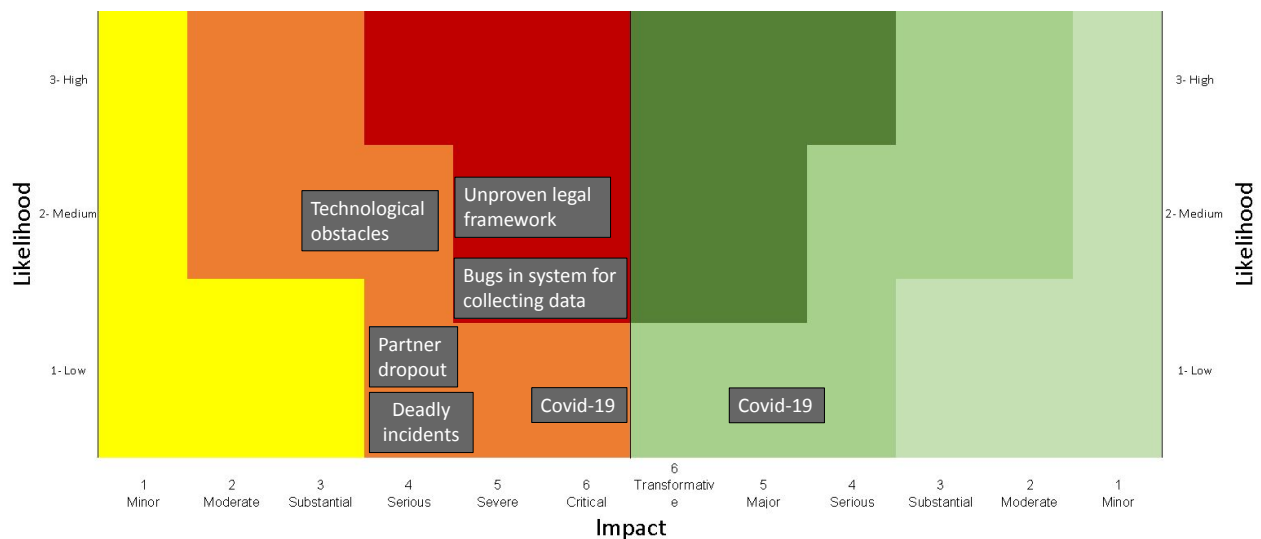


Figure 8: Double Probability Matrix

Another way of determining how to respond to risk is with **ARTA** (**A**void,**R**educe,**T**ransfer,**A**ccept) and for opportunities **EESI** (**E**xploit, **E**nhance, **S**hare, **I**gnore).

According to the double probability matrix and based on the likelihood for Covid-19 the response for the risk of Covid-19 should be *transfer* and for the opportunity should be *share*. This is an example of where theory does not match practices. There is no other stakeholder that is able to manage the risk of Covid-19 better. Instead, the proper response is to *reduce* the impact it has on the project. As for the opportunity of Covid-19, it is not possible to *share* with a partner, maximizing the chance of it happening and benefits. Instead, the correct response to this is to *exploit* the opportunity and get an extension of the project. This is what they ended up doing in the project and the project was prolonged for 6 months. In this case, the response from theory does not match reality.

7.2 Scope Creep

The definition of scope creep is the controlled/uncontrolled changes to a project's scope after the project begins. For the LINC project major changes were made to the work package structure, redefining deliverables, and how stakeholders were involved in the project. Firstly, DTU received an additional deliverable, an app used while riding the shuttle to track the ride and how long users would wait for the bus. Originally IBM was meant to develop this. Secondly, Loop City left the project and major changes had to be made related to the light rail. Thirdly, throughout the project changes can only be made three times to the project description/scope, and it had to be approved by UIA. In their third approval they made 70 major changes according to Jens Dahlstrøm.

“(...) we had three windows where we could make major changes. (...) So in the last one, I think we made like 70 changes to the project.”

— **Jens Dahlstrøm**, Operations manager LINC, DTU

This is an unusual amount of changes made late into the project. This is one of the reasons the project is not following the paradox of project planning, as many important decisions were made late into the project. But these changes were necessary for the project to be completed.

7.3 Reflection and Recommendations

Looking back in time, some risks could be predicted better. Choosing EasyMile as the bus supplier was understandable decision, based on the fact that the price was better than what Navya offered, and the Nobina had already worked with it in Sweden. Though their in-proper planning and lack of knowledge about the legislation resulted in unpredicted delays because of e.g. having to modify the shuttle to make it comply with Danish rules. The modification of the bus had to go through EasyMile to be accepted. Luckily they accepted these changes.

Using the Fishbone diagram, it is clear that every work package is dependent on the legislation. From this, it is clear where the main focus in the planning process should have been. More effort should have been put into understanding the legal framework before picking a shuttle. Further, the system development for data collection also resulted in time delays, although this process could have been started earlier.

Overall, the project was very lucky to survive and all of the 90 mitigation actions being accepted by UIA. Without Covid-19 the project would likely not have gotten the required extension resulting in them not being able to deliver the deliverable, and stakeholders would have had to pay back the grant money.

In the end, the project does not follow the project paradox. Many important decisions had to be made last minute in the project in order to avoid having to pay back the grant and there were still a lot of unavailable knowledge e.g. because of Covid-19. Kenneth words this really well from one of his PowerPoint presentations.

“I simply don't know where we would have been without Covid-19.”

— **Kenneth Jørgensen**, Senior Project manager LINC, Gate 21

References

- [1] T. U. L. of Europe, “UIA Journal from 2018,” https://www.uia-initiative.eu/sites/default/files/2019-02/Albertslund_TUPPAC_Journal.pdf, 2018, [Online; accessed 18-August-2021].
- [2] —, “UIA Journal from 2019,” https://www.uia-initiative.eu/sites/default/files/2020-05/Albertslund-TUPPACLINC_Journal.pdf, 2019, [Online; accessed 18-August-2021].
- [3] FDM, “Nu kører Danmark uden fører,” <https://fdm.dk/nyheder/nyt-om-biler/2020-03-nu-koerer-danmark-uden-foerer>, 2020, [Online; accessed 4-August-2021].
- [4] Navya, “First autonomous shuttle buses in daily operation on danish roads,” <https://navya.tech/en/first-autonomous-shuttle-buses-in-daily-operation-on-danish-roads/>, 2021, [Online; accessed 4-August-2021].
- [5] L. Project, “Linc Project,” <https://lincproject.dk/>, 2021, [Online; accessed 4-August-2021].
- [6] T. U. L. of Europe, “Transforming Urban Planning Providing Autonomous Collective mobility,” <https://www.uia-initiative.eu/en/uia-cities/albertslund>, 2021, [Online; accessed 4-August-2021].
- [7] UIA, “Albertslund TUPPAC UIA Expert Journal1,” <https://www.uia-initiative.eu/en/uia-cities/albertslund?fbclid=IwAR2Pbq3XflvNC-TTcMZGZooez7dO0qW9aGBgQo1BpvrwDGTMXKZyPDpN1jo>, 2018, [Online; accessed 6-August-2021].
- [8] T. U. L. of Europe, “UIA Guidance,” <https://www.uia-initiative.eu/en/call-proposals/guidance>, 2021, [Online; accessed 18-August-2021].
- [9] C. Thuesen, “Purpose slides from lecture, slide 14,” 2019, [Online; accessed 18-August-2021].

A Gantt Chart

Project Activity Plan and Scheduling for WP 4 and WP 5

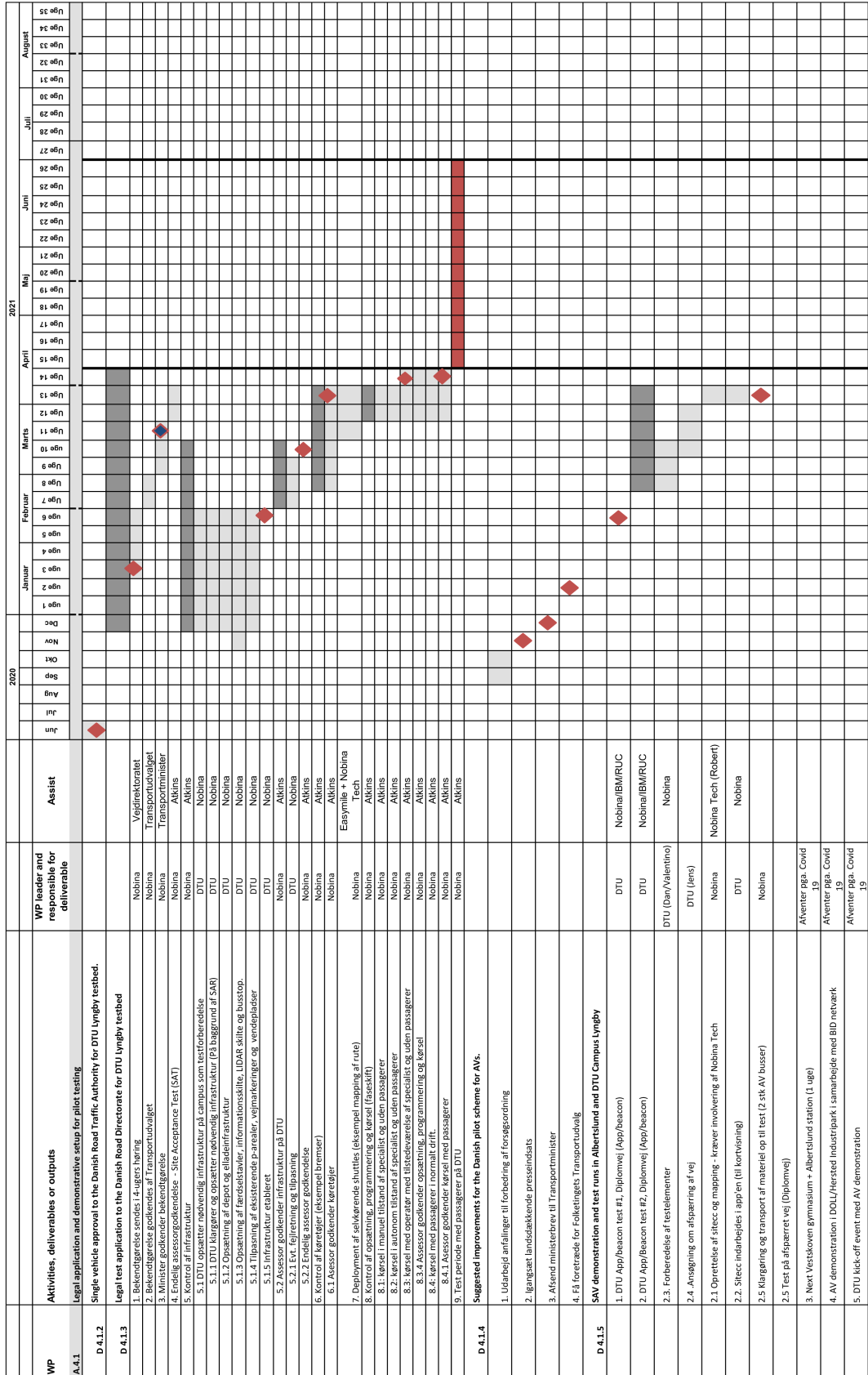


Figure 9: Gantt chart for work-packages 4 & 5 part 1

