Skellefteå future mobility and transportation system

- *An innovative and resilient municipality that connects people from all over the world*

Authors: Oskar Enocksson, Emma Westling, Julia Knutsson, Chao-Yuan Liu, Julián Giraldo

Executive summary

To create a sustainable transport sector in Skellefteå municipality in 2050 four different solutions, that can be combined in various ways, have been developed and tested. The different solutions cover different means of transportation such as cars, snow mobiles, drones, and boats. They also include different kinds of fuel such as electricity, biofuel and hydrogen. The solutions also cover land use policy, social policy, economic policy and how the vehicles are organized, i.e. are they driven manually or are they autonomous. One solution is also completely virtual. To implement these solutions different changes are needed in the society both on a structural, cultural and technical level. Different changes are needed in policies and regulation, infrastructure, citizens behavior, and new technologies must be implemented. The first step will include information to citizens about the new ways of transportation, "sharing is caring", and new technologies. It will also include the construction of infrastructure that fits the new transportations needs. Later on new policies and regulations should be in place to further improve the transportation. Five experiments have been suggested to get evidence on what solutions will be the most effective and they are related to technology, governance, social culture, and business models. All experiments are suggested as a way to reach the most sustainable solution.

To evaluate the solutions, pathway, and experiments from a sustainability perspective five criteria are presented; (1) accessibility, (2) safety, (3) environmental impact, (4) efficiency, and (5) affordability. The solutions are evaluated from the criteria with a score of 0-5 points. Further, to consider uncertainties and external environments, future scenarios have been developed to test how robust the solutions could be. The scenarios are based on two key uncertainties, population growth and digitalization, and a total of four scenarios were developed, namly (1) buzzing retro city, (2) calm vintage town, (3) discrete virtual hub, and (4) vibrant cyber city.

The solutions, pathway, and experiments could improve the transport sector from both social, economic and environmental aspects. The current situation in Skellefteå is that owning a vehicle is the easiest way to get around and public transportation is most common in the city center and the main fuel is still fossil based. Many different stakeholders are involved in the transport sector, such as the civil society, the municipality, construction industries, energy companies and the Swedish government. All stakeholders have different power and interest in the transport development, where the municipality scores high on both. As for the needs and function of the transport system the most important is that the transportation of both people and goods will be easy and accessible.

The whole report aims to investigate how a sustainable transport sector in the municipality of Skellefteå could look like in 2050 and what is required to get there. To reach this aim a future vision was created for the municipality; "An innovative and resilient municipality that connects people from all over the world".

1 Introduction

The world today is experiencing rapid urbanization, more than half of the world's population are living in urban areas, and until 2050 it is expected that 66% of the population will live in urban areas (Bodo, 2019). The reasons for this are several, and the increase of people living in urban areas comes with environmental problems. Of the global CO_2 emissions cities stand for about 70% (Sharifi, 2021). Many agree that this must change and that cities need to get more sustainable, and for a city to be sustainable several elements need to be considered. Elements such as education, energy, buildings, and transport are important to address when planning for a sustainable city (Sodiq et al., 2019).

Sustainability is a concept with various interpretations, but one of the most common definitions is the one of three dimensions shown by three circles in a 'Venn diagram'. Where the circles overlap the sustainability is found. The social, economic, and environmental/ecological dimensions are what these three circles represent, and it is only when all three are achieved that one can talk about sustainability or sustainable development (Purvis, Mao and Robinson, 2019). To get a more concrete view of sustainability the United Nations (UN) formed 17 Sustainable Development Goals (SDG), and these 17 goals work as an action plan and is called Agenda 2030 (United Nations, n.d.a). One of these goals (number 11) is called Sustainable cities and communities, and the second target for this goal is

> *"By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons" (United Nations, n.d.b).*

The transport sector stands for about 25% of the world's CO_2 emissions (Zhao et al., 2020) and this fact must be addressed in our urban world. In Sweden this number is slightly higher, the transport sector stands for about one third of the total CO_2 emissions and the government is constantly working on lowering this number and to build a sustainable transport sector. Mobility is important, it is necessary for people to move and to have a working transport sector that can deliver materials and goods. The Swedish government is planning an electrification of the Swedish car fleet which means a change in the infrastructure with electric roads and more charging stations. This is due to the high emissions that need to be addressed (Regeringskansliet, n.d.).

Because of the high emissions in the transport sector the ambition of an electrified car fleet is necessary, however this change cannot happen easily and over a night. This is partly because of the carbon lock-in in the transport sector. This lock-in exists on four levels, the firm level, industrial level, governmental level, and societal level. This lock-in makes it harder for smooth transitions since it involves a big part of society. Today, only 6% of the car fleet in Sweden consist of rechargeable cars (Elbilsstatistik, n.d.), one argument for this is that many customers think that combustion engine vehicles are more reliable than a battery electric vehicle. Combustion engines will "take you where you want to go" whilst other fuels (like electricity) will not. This is an example of lock-in created on a societal level (Klitkou et al., 2015).

Combustion engines have been developed and improved, they have been specialized and refined to be as effective as they can possibly be. The infrastructure is built around combustion engine vehicles with e.g., gasoline stations around every corner and this is not just in Sweden, this infrastructure crosses the national borders (Klitkou et al., 2015). There are also subsidies for fossil fuels, it is still cheaper than it should be to buy both diesel and petrol (Dóci, 2022). Further, in media combustion

engine vehicles are promoted through commercials with celebrities for the new edition of a certain car (Volvo Car Sverige, 2014) and trough movies such as Fast & Furious (Universal Pictures UK, 2020) that reinforces norms that it is “manly” to drive nice cars with a great engine sound. All these examples show how the lock-in for combustion engines affect our transport system today.

Many would probably agree that our transport sector is unsustainable and that a change is necessary. A city in Sweden that today is preparing for rapid growth is Skellefteå, with new industries such as Northvolt Skellefteå is preparing to grow, and 90 000 citizens are estimated by 2050 (Skellefteå municipality, n.d.a). Skellefteå as a municipality has a goal that this transition will happen in a sustainable manner and must therefore work in several areas at the same time to make it a reality . One of the areas that needs to be addressed is of course transportation. Skellefteå aims for a doubling in collective transport travels (Skellefteå municipality, 2022a) and they promote bicycle and walking and are constantly working on the safety and accessibility for people who choose to bike or walk (Skellefteå municipality, 2022b). However, more than bicycles and collective transport are needed to get a sustainable transport sector.

A sustainable mobility and transport sector must be open to new solutions and innovations (Sodiq et al., 2019) and Skellefteå, a city high up north in Sweden, could be a leading star for how to implement new ideas in a sustainable way. To get out of the lock-in we see today and to make a transition in the entire car fleet we are dependent on new interrelations than before, like electricity instead of oil, batteries instead of regular motors and other raw materials (Nykvist and Nilsson, 2015). The transition needs to happen fast and it will make big changes in the transport sector as we know it today. Therefore, this report aims to investigate how a sustainable transport sector in Skellefteå could look like in 2050.

1.1 Aim and objectives

The aim for this project is to investigate how a sustainable transport sector in the municipality of Skellefteå could look like in 2050 and what is required to get there. In order to reach this aim, 2 objectives have been formulated: (1) get an understanding for lock-in and transition theories in the transport sector, and (2) through modular Participatory backcasting create a vision and possible solutions for a sustainable transport sector.

1.2 Methods

This study uses Participatory Backcasting as a process to develop a vision, solutions and pathways towards an attractive and sustainable Skellefteå in the year 2050. In order to understand concepts and gather facts for a credible report, a literature review has been conducted. Question and answer (Q&A) sessions with Skellefteå municipality and a semi-structured interview with a stakeholder have provided additional information for the upcoming solution. The framework Modular Participatory Backcasting has been studied together in groups and exercises of all 13 modules have been carried out during seminars. These exercises have been performed in groups using a MIRO board software.

1.2.1 Literature review

A literature review has been conducted to gather information on sustainable mobility solutions and related systems. For general facts about Skellefteå Municipality, Skellefteå's own website has been used as first-hand information. For the implementation of Modular Participatory Backcasting the

website mPB (n.d), has been used. Other search engines mainly used include Google scholar and ScienceDirect along with keywords such as Participatory backcasting, Sustainable development, and Sustainable transportation.

1.2.2 Q&A session

Two Question and Answer sessions have been held during the project. The two sessions consisted of one hour long zoom meetings, where questions about Skellefteå were asked to representatives from Skellefteå municipality.

1.2.3 Semi-structured interview

Two semi-structured interviews have been conducted. The respondents are people who currently live in Skellefteå. The questions cover what the respondents think about Skellefteå's strategy for sustainable development and about the municipality's transport system.

1.2.4 Modular Participatory backcasting

Modular participatory backcasting is a method for producing a desirable future together with studying the approach to get there. The manual primarily used in this study is mPB (n.d) which is based on 13 modules. Each module has been carefully studied and used in the report. The number sequence of the modules was initially followed but during the process the modules have become flexible and have been studied back and forth to reach a solution that works for the focus of this report. The modules have been studied and discussed together in the group, both at seminars and in-between meetings.

2 mPB concept

Modular participatory backcasting is based on the principles of modularity, participatory modeling and transdisciplinarity. Modularity means that the design of the framework is built on modules that are dependent on each other, but the components of each module have relatively little interconnection. Participatory modeling means that the methodology of the modules is based on participation with different stakeholders, and participatory stakeholders help to reach more relevant insights. Transdisciplinarity is based on linking a scientific and societal problem to find a common solution. The 13 different modules of participatory backcasting are described in the following section.

2.1 Problem orientation

The first module focuses on the formulation of the problems to be solved. It also addresses key sustainability challenges that may arise during the process (Pereverza et al. 2018). The work steps consist of the identification of stakeholders and their perspectives on the problem, the identification of sustainability challenges and the identification of the socio-technical system along with delimitations (mpb, n.d).

2.2 System boundaries

Module two, named System boundaries, aims to develop boundaries for the socio-technical system. These boundaries can include temporal, political and spatial boundaries (Pereverza et al. 2018). It also develops a description of how the different parts of the system relate to each other (mPB, n.d).

2.3 Current situation

Module number three, Current Situation, is designed to analyze the current state of the sociotechnical system. The analysis should also address relevant characteristics of the system (Pereverza et al. 2018). The work process starts with determining the type of information needed and then identify the main strengths, weaknesses and problems of the system (mPB, n.d)

2.4 Stakeholder analysis

The fourth module, stakeholder analysis, aims to find actors related to the problem. It should not only be the main actor that is analyzed but also other actors that can be linked to the problem (Pereverza et al. 2018). The work process starts with finding actors, then identifying the power and interest of the different actors for the problem in question. At last, common interests are developed between different actors (mPB, n.d). An important part for the outcome of the actor analysis is to also look at the future roles of new actors and their potential position regarding the problem (Pereverza et al. 2018).

2.5 Needs and functions

The fifth module, Needs and functions, is used to examine current and future societal needs, necessities, and system functions. This module promotes innovative developments that can lead to for example different technological solutions or new business models (Pereverza et al. 2018).

2.6 Vision

The sixth module, Vision, aims to develop a vision for the future. In order to create a desirable and shared vision, all stakeholders should be considered (Pereverza et al. 2018). To create such a vision, the work process should start with exploring appropriate keywords associated with the desired future (mPB, n.d.).

2.7 Criteria

The seventh module, Criteria, aims to produce measurable criteria. These criteria serve as targets to achieve the desired vision (Pereverza et al. 2018). The work process starts with brainstorming and then each criterion is ranked according to its importance. It is desirable that all criteria are quantifiable (mPB, n.d.).

2.8 Drivers

The eighth module, Drivers, is used to investigate external drivers that may influence and interfere with the system. The module results in trends and uncertainties that are used to produce a future plan. The future plan consists of four different external scenarios (mPB, n.d.).

2.9 Solutions

The ninth module, Solutions, is about developing ideas for solutions that will make the vision a reality. The solutions should be limited to the socio-technical system (mPB, n.d.).

2.10 Solution testing

The tenth module, Solution testing, consists of selecting a final solution for implementation. The module includes data from module seven-Criteria, eight-Drivers and nine-Solutions. Each solution is evaluated against the criteria and scored with numbers. After that, solutions are evaluated according to their robustness using the four different scenarios of the future plan (mPB, n.d.).

2.11 Pathway

The eleventh module, Pathway, aims to explore changes needed to achieve the chosen solution and vision. The changes can be technical, cultural or institutional and should be linked to different stakeholders. A timeline is used to map out the various changes at the appropriate time, and then possible drivers and barriers that may arise during implementation are explored (mPB, n.d.).

2.12 Action plan

The twelfth module, Action Plan, aims to produce a short-term but detailed action plan. This action plan is the first step towards achieving the vision. The plan includes deadlines, responsibilities, specific tasks and milestones. The Action Plan is being used to identify the actions required for the various changes developed during Module Eleven-Pathway (mPB, n.d.).

2.13 Follow-ups

The thirteenth module, Follow-ups, consists of following up and monitoring results and developing follow-up activities. The module deals with long-term planning (Pereverza et al. 2018).

3 Results

3.1 Problem orientation

The aim of this project is to support the municipality of Skellefteå in developing towards a sustainable and attractive city by 2050. Rapid population growth is expected in the coming years due to new industrial establishment, which is identified by the group as the main challenge of this project. According to the first Q&A session (Johansson and Ulander, 2022), in addition to increasing people's interest to continue using public transport, the municipality is also trying to encourage those who rely on their own vehicles to switch to public transport. Therefore, the main challenge leads to related challenges of providing a new and sustainable mobility system and creating acceptance for this system, which are the two core problems of this project. Additionally, the environmental impacts of mobility system expansion and the rising fossil fuel taxes in Sweden (Holmström, 2022) serve as the motivation for a sustainable mobility system. Such environmental and economic concerns are sustainability challenges relevant to the main challenge.

3.2 System boundaries

The temporal boundary of the problems to be addressed is from now until 2050, with a milestone of the year 2030. The two boundaries of the sociotechnical system defined by the group are presented in Figure 1. The geographical boundary is the Skellefteå municipality, represented by the inner dashed square. Within the square are the mobility system and the stakeholders, including the administration of the municipality, local citizens, local industry and companies. Surrounding the Skellefteå municipality is the outer dashed square representing the geographical region of Västerbotten and the nation of Sweden. Between the two squares are the administration of the county, the Swedish government, non-governmental organizations (NGOs) and the Saami people.

Concerning mobility, the interrelations between different stakeholders within the Skellefteå municipality are the transportation of people and goods, and the collaboration and interaction between different stakeholders. The administration of the municipality manages and funds most of the incremental or radical changes of the mobility system. Local construction and service companies conduct the expansion and construction, and local citizens and industries act as the end users of the mobility system. Between Skellefteå municipality and the rest of the country, the interrelations are the movement of people and goods, the regulatory forces of government policies on the municipality, and the influence of non-governmental actors. The administration of the county and the Swedish government regulate the operation of the municipality and can be in charge of part of the mobility system.

Despite being part of the local citizens, the Saami people have been separated from local citizens to highlight the potential impact of the mobility system on their traditional reindeer herding lifestyle. NGOs influence the government of the municipality by conveying the voices of people and nature to different levels of society. Despite having different degrees of involvement in the construction and operation of the mobility system, these stakeholders rely on mobility services, and the operation of the services relies on the stakeholders. Such dependence is represented by the two-way solid arrows. The two-way dashed arrows represent the communication or regulation between stakeholders.

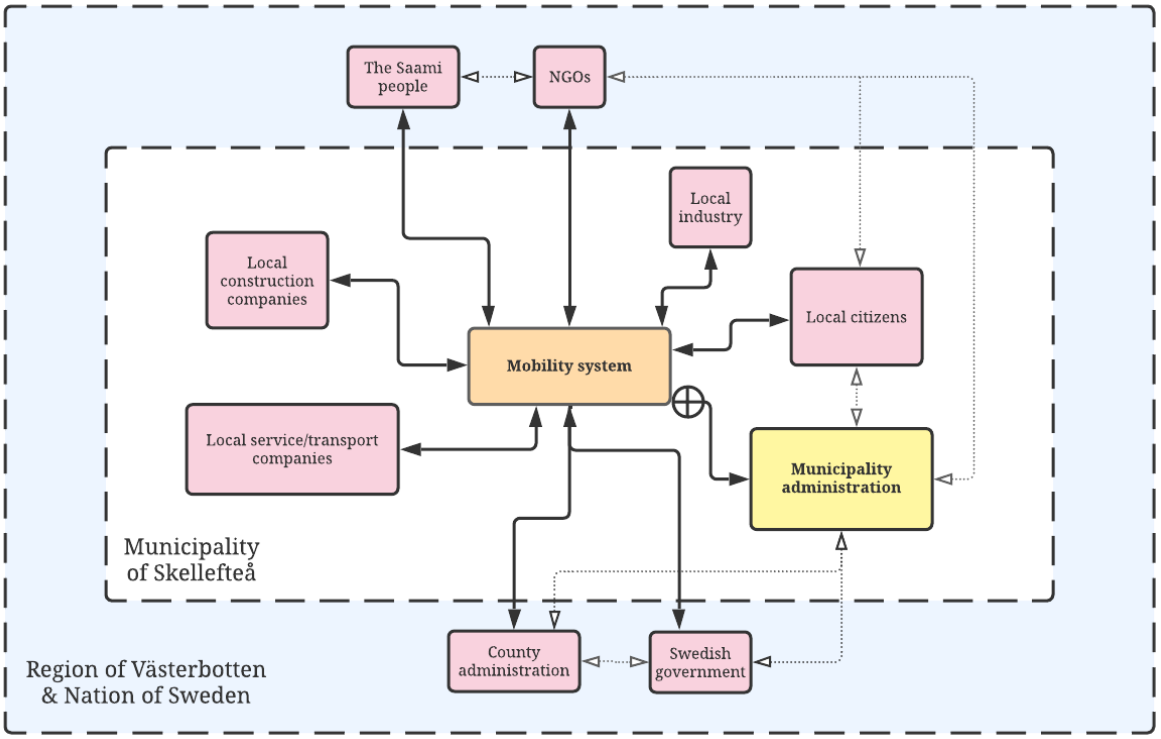


Figure 1. *Relational graph of the system boundaries*

Not presented in the graph but also considered in the system boundary is the ecological system as in ecological well-being, which is also taken into account in this project. Instead of an anthropocentric, human-centered approach to address the problems, the group aims to adopt a more inclusive approach. Thus, in addition to the identified stakeholders representing different elements of the socio-technical configuration, which will be analyzed in the stakeholder analysis section, the wildlife is also seen as a group influenced by the problems and decisions.

3.3 Current situation analysis

The current situation was examined by analyzing the responses obtained in the Q&A sessions and the semi-structured interviews. According to the semi-structured interviews (Lo and Lu, 2022), Skellefteå does not have its own train station. To travel between Skellefteå and other parts of Sweden by train, one has to take the bus to Umeå first. Within the city center, commuting on foot is totally feasible. From residential areas located in the suburbs to the city center, a bus ride of approximately 30 minutes is needed. The service frequencies of most bus lines are not high, with a headway of 30 minutes being the norm. As for now, owning a car is a must to settle down in Skellefteå, which can be considered a weakness of the current system. Since most people commute by cars, taxi service is relatively rare in Skellefteå. Concerning sustainability, the main problem may be the increase of waste and emissions, since electric vehicles (EVs) are not that widely used in Skellefteå yet. If the usage of EVs were to increase, the burden of public charging stations and the grid have to be taken into account.

Information about the current state of Skellefteå was also received through the two Q&A sessions with municipality administrative representatives (Johansson and Ulander, 2022; Ulander, 2022). Some parts of the city center are close to experiencing traffic congestion with the current traffic flow. A lot of focus is put on a section of the east-west bound road 95 due to the location of a Northvolt factory. While this is another weakness of the current system, this can also be an incentive for people to switch

to public transport. Currently, public transport is more popular for inhabitants who live close to a main bus line and work in central Skellefteå or those who don't need to change bus lines to get to their workplace. Public transport is not widely used by families with children of younger ages that need to be dropped off and picked up at school, and the use of public transport generally decreases after people obtain their driving licenses. In addition to improving existing structures while taking into account the social and environmental aspects of sustainable development, the municipality is trying to turn to digital solutions and is investigating the possibility of using autonomous vehicles.

Selected comments from the "citizen dialogue" can be found on the website of the Skellefteå municipality (Skellefteå municipality, n.d.b). Concerning transportation to and from Skellefteå, the Norrbotniabanan train track, is the most important to develop according to 38% of the respondents and is thought to be beneficial to the development plans of the whole of northern Sweden. Two other areas that are prioritized by the citizens are bus services and pedestrian- and bicycle-oriented spaces.

3.4 Stakeholder analysis

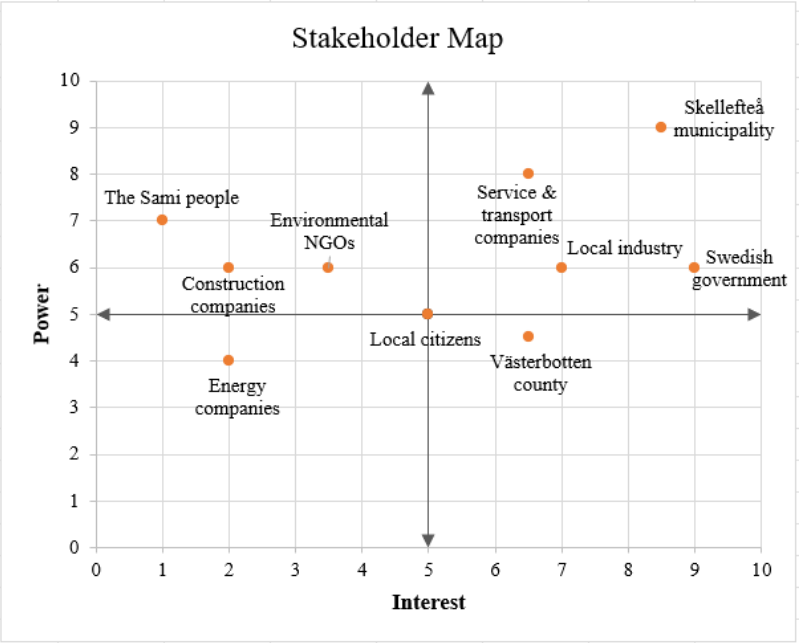
The different stakeholders listed below (see Table 1) have been identified after taking different sectors in Skellefteå into consideration. Included are those stakeholders and actors who might be affected by potential changes in the mobility system and can help to shape decisions based on a range of perspectives and information.

Table 1. Som potential stakeholders that are relevant to include in a sustainable mobility system

Stakeholder list	
General	**Spcific branches**
Civil society	Tourist organisations Outdoor life org. Motorsports org. Cykling org.
Skellefteå municipality	Visit Skellefteå, tourist org.
Västerbotten county	…
Swedish government/authorities	The Swedish Transport Administration RISE Research Institutes of Sweden Vinnova The Swedish Agency for Innovation Systems The Swedish Energy Agency IVL Swedish Environmental Institute The Swedish Environmental Protection Agency
The Saami people	…
Construction	White arctitecture HENT Sverige AB
Industry	Northwolt Boliden
Service/transport companies	Move about E/go Skellefteå buss
Energy companies	Skellefteå Kraft
Non-governmental organisations	The Nature Conservation Association

The municipality, Swedish government, local industry, and the service/transport companies can be considered as powerful stakeholders due to the fact that the transition of Skellefteå into a sustainable mobility system depends in big part on the contribution they can bring. Northvolt is a big industry in the market of batteries where its gigafactory Northvolt Ett is located in Skellefteå and it is vital in the transition of Skellefteå because it can attract a large flow of new citizens to the city and help stimulate the local economy to reach the population goals for the municipality faster. But this large flow of new citizens also means the necessity of developing mobility infrastructure and expansion of the transport system in Skellefteå.

Table 2. Suggested power/interest relationships between stakeholders and sectors connected to the mobility system.



Analyzing the stakeholder's map of power against interests, it is easy to conclude that the high interest stakeholders are the governmental authorities and the local industries of Skellefteå, because by accomplishing the transition they will reach their goals and the accomplishment of their actual interests. On the other hand, the low interest stakeholders are more related to the ones who can actually enjoy the benefits of the transition but are not completely aware of them right now.

Based on the analysis carried out by Avelino and Wittmayer (2016) it can be concluded that big companies or industries (like Northvolt, construction companies, and transport companies) have a nature of formal power. They are private and profit based, and play a key role in Skellefteå's transition. But with the passage of time, the role and nature of power of those companies or industries can change into a more informal one. For example, if Northvolt starts to listen to its workers demands and issues related to the transportation from and to their facilities. A new stakeholder could potentially be raised, because Northvolt's workers will start to play a role with a bit more power than the original citizens' stakeholder which will increase also the interest of Northvolt to push harder for new transport solutions that can solve the issues of its workers to assure their performance to the company.

According to Avelino and Wittmayer (2016), transport and service companies will have a big interaction with other roles of stakeholders and with different powers as the citizens, saami's community, etc. because population is completely linked and involved to the transport necessities , due to the fact that they are the actual users of it and with this interaction, the web of roles can lead to a co-evolution of the mobility system while taking into account variety of perspectives. Furthermore, it leads to a help for the most powerful stakeholders that in the beginning have some interests to shape them better through the passage of time and experiences to deliver a more accurate solution, due to their constant interactions with the citizens, saami community and other active stakeholders that might interrelate and influence them..

Finally, as previously explained , some transformations in the stakeholders can happen due to different interests which leads new stakeholders to consider while the time is running. For example The Swedish Transport Administration is responsible for drawing up the regulations and ensuring their accomplishment of the accessible, high quality, safe and environmentally friendly new means of transport but the Västerbotten Region is in charge of planning and implementing the regional road network and which traffic must be prioritized. Where it can be found that the potential conflicts between these two stakeholders are strictly related to the area of influence, but with a well designed collaboration between them, the final transport system will also satisfy the interests of other stakeholders that don't have the same amount of power.

3.5 Needs and system functions

According to Skellefteå municipality trafikprogram (2020):

> *"The transport system must be developed in a sustainable way and must be characterized by efficient transport with good coordination between different modes of transport where resource-efficient travel is a priority"*.

This quotation resumes in big features what Skellefetå's municipality needs for their mobility in order to consider it fulfilling the whole journey and making it simple to change between means of transport for everyone. But the train traffic is one of the top priorities to develop further because by building Norrbotniabanan railway would stimulate efficient travel, and expanded freight transport, leading to enhanced connections throughout the railway line which will make it easier to reach the city and taking in consideration the travel patterns of the different individuals of Skellefteå.

On the other hand, the efficient and environmentally-friendly sea transport offers a diversity of options to consider for freight transport and citizens to expand Skelleftea's horizons and to connect the northern part of the Scandinavian countries. As a male Skelleftea's citizen around 55-64 years old has stated, *"Train traffic is a good way to transport goods and people, further, if the coastal cities are tied together the whole of norden Sweden will develop"* (Skellefteå municipality, n.d.b).

Some comments from actual citizens to take in consideration for the identification of challenges are the words stated by a male Skelleftea's citizen around 45-54 years old*"One should look to see that people can travel collectively at least inside the municipality of Skellefteå, with regard to working hours, schools, etc."* and by a female Skellefteå's citizen around 45-54 years old who claims more options to conserve nature but improving mobility as follows

"We need to strengthen the conditions for keeping our city green and pleasant, so that we can move with environmentally friendly and health-promoting means. There is still a lot to be desired and I keep my fingers crossed that more is being invested in pedestrians and cyclists" (Skellefteå municipality, n.d.b).

Following Skellefteå municipality (2020) traffic program *"community planning needs to take place in collaboration with inter-municipal, regional and national planning"*, but also consider the demands of different kind of citizens of Skellefteå as the new Asian engineers of Northvolt coming there, the citizens' opinions and Saami representatives. Those different kinds of citizens have similar needs and synergies by studying them as individuals and group levels that must be satisfied.

Three challenges identified for the mobility system of Skellefteå are: Requirement of good road connections to Skellefteå's airport and seaport, because by assuring it, the easy and high flow of goods and passengers fluctuating from and to Skellefteå will increase considerably with a developed infrastructure.Finally, the societal function involved in this challenge can be the logistics and transport, while its linked risk would be a lagging in the construction of those roads which will negatively impact the travel patterns of Skellefteå's citizens and tourists.

The national climate goals related to transportation is another interesting challenge.With the reduction of air pollution, the nature of Skellefteå will remain free and accessible to everyone, a fact that will enhance the attractiveness for tourism and new residents of the city. Thus, the efficiency in energy use and reduction in greenhouse emissions will positively impact other good activities for the citizens such as agriculture. Finally, the societal functions related to this challenge are the public health, sanitation and food considering the potential healthier environment by accomplishing it. While its associated risk is the unmanaged or unlimited construction of new roads or mobility infrastructure, which can considerably decrease the green zones and nature of Skellefteå, directly affecting the saami people, their animals and assets.

According to Skellefteå municipality (2020) traffic program *"An easy travel on human terms"* means affordable and accessible to everyone, because making the travel or mobilization of the citizens through the municipality easier and diverse will increase productivity, also reducing time waste previously needed to reach destinations such as jobs, schools, etc. The societal function linked to this challenge can be the economy, engineering and public works, which will be enhanced due to the possible productivity increase of the users in their works.

3.6 Future vision

From the previously identified problems, a desirable future vision is created. For the development of the future vision, the following keywords have been identified: economic, environmental, and social-sustainability, diversity, equality and inclusiveness.

'Sustainability' is often used by businesses for their vision of the future. What is important to remember is that sustainability, as mentioned above, stands for several things: economic, social and environmental sustainability. Using these keywords, all stakeholders studied in this report could work towards a future with a strong economy that benefits both the stakeholder in question and the municipality, for a shared and inclusive society, and with as little environmental impact as possible. Sustainability is a keyword that also fits well with Skellefteå's already existing sustainability goals, which include: Environment and Climate, Welcoming and Inclusive, Responsible Economy and Fair Conditions, and Enduring and Positive Impact (Skellefteå municipality, n.d.c.).

Diversity is a key word that fits into a growing and modern society and the desired population growth in Skellefteå should contribute to a diverse society. The population should be a mix of different human characteristics that can contribute to learning and industries can benefit from individuals having different skills. Public transport should be useful for all people no matter appearance or ethno-religious background and Skellefteå municipality will, with a diverse society, have better conditions to get an even bigger population and a more integrated society.

Equality should exist among all stakeholders and contribute to a society where everyone is treated the same way. A citizen living outside the city center should have the same conditions regarding transport

as a citizen living in the center. Choice of work and place of residence should not be a problem, everyone should have the opportunity to settle in a place they like. Equality in terms of industries should reflect that everyone is treated on an equal level and between industries in the municipality there should also be equal opportunities. An equal society contributes to a positive value for both Skellefteå and Sweden as a country and this is something Skellefteå municipality, government and authorities should strive for.

Inclusiveness is a key word that can be compared to both diversity and equality. An inclusive society leaves no one out and accepts people's different lifestyles and cultures. Skellefteå municipality together with government and authorities can work towards an inclusive society that does not exclude any opportunities to grow. Based on these keywords, a vision has been created that links the above expectations of the future:

"An innovative and resilient municipality that connects people from all over the world".

The vision describes an innovative community that includes people with different characteristics and a community that values new technology in order to be accessible. The vision also highlights how population growth can be integrated in Skellefteå in an equal way.

3.7 Criteria

Through discussions within the group, a consensus was reached to include the criteria and sub-criteria being presented in Table 3. The underlying idea was to use criteria deemed to have the closest connection to mobility, and how they could be measured in different ways. It would be hard to weigh and identify the single most important criteria being included, since it is assumed that they are all necessary to form a sustainable mobility system in Skellefteå. However, attention has been taken to the statements made by the municipal representatives and what the specific issues and needs of the mobility system are. If one criteria would be chosen as the most important, it would probably be environmental impact because of the close connection to some of the most urgent challenges of the modern world: climate change and biodiversity preservation.

With this in mind, accessibility is considered important to include since it is at the core of a functioning mobility system. If it was not accessible, then no one could use it properly. The percentage of people using public transport on a daily basis were assumed to give data of how accessible public transport is, as well as how many mobility options are available at any given time during the day. Safety was also essential to include, since no one would like a mobility system that was highly unsafe. Measuring the amount of accidents per month and year would give an indication as to how safe it is. Furthermore, environmental impact was assumed to be important because of the various commitments Skelleftå have made to environmental sustainability. Assessing the impact of the mobility system on the surrounding ecosystem services during construction and management could be made qualitatively and quantitatively, and emissions could be measured quantitatively.

As for efficiency, this criterion focuses on the connectivity between mobility options and how the parts of the system work together. A system that has a higher level of synchronization is assumed to be more efficient, with regards to the time it takes for people to travel in the municipality. Lastly, affordability was necessary to include since no one would use transportation options if it was too

expensive. This relates both to the investment costs for the municipality, and the price that the citizen has to pay for whatever mode of transportation that is chosen.

Table 3. *Illustration of chosen criteria and sub-criteria to evaluate solutions against.*

Criteria	Sub-criteria
Accessibility	% of people using public transport Number and share of various mobility options
Safety	Accidents/month and year
Environmental impact	Qualitative or quantitative impact on ecosystem services Kg of CO2 & NOx emissions Kg of particle emissions
Efficiency	Degree of integration and connectivity in mobility system Time of travel (minutes/hours)
Affordability	Investment and maintenance costs for municipality (SEK) Price/kilometer for citizens (SEK)

3.8 Driver analysis

The group identified two drivers that were judged to be both uncertain and impactful: population growth and digital development. At the start of the process, economic growth was also considered a potential alternative to population growth. However, economic growth is to a large degree related to population size, because more inhabitants lead to higher tax incomes for the municipality (and thereby greater support for mobility infrastructure investments). Apart from this, though, the rationale for choosing population growth was also that it involves a larger set of aspects than just economic growth, e.g., cultural exchange and innovation which could be considered relevant when trying to fulfill the visions of the mobility system.

The doubts of choosing population growth has not been based on its potential impact, but rather its uncertainty. During the Q&A sessions with the municipality, a high population scenario seemed more or less expected, and the question was rather about how to enable people to move in, settle, and stay in Skellefteå. Even if this is the case, the group assessed that omitting population growth would be to disregard an essential driver in this case. Furthermore, it is not known what aspects were taken into account in the municipal prognosis, meaning some factors might make the evaluation more uncertain than previously expected. Since a large degree of the development plans revolve around the establishment of Northvolt events that might affect those plans can have a large impact on whether people move in or not, e.g., if it offers jobs in other cities of Sweden.

The digital development rate could arguably also be assessed as less uncertain, but with a potentially huge impact on mobility and other areas of society. Based on the rapid improvements being made in this sector, it might seem unreasonable to assume that it will not continue in the same fashion. However, the attitude in the group is to leave space for unexpected changes which might lead to scenarios with less digitalisation, although it might not be too likely. The question might rather be to what extent digitalisation will have an impact in society in general, and the mobility system in

particular. In conclusion, four external scenarios are articulated in Figure 1 based on population growth and level of digitalisation. It is worth mentioning that population growth and digitalisation both depend on events outside and within the municipality.

Figure 1. *Future scenarios with population growth and digitalisation as the key uncertainties. The high and low scenario for population growth is not necessarily connected to Skellefteås own migration prognosis, but can go beyond that.*

3.9 Solutions

3.9.1 Identification of system dimensions

Six different dimensions with a maximum of four various states for each dimension have been identified (see Table 4). Three of the dimensions concern policies (C, D, E), two are more technologically related (A, B), and one covers how the mobility system is organized (F). It was acknowledged that creating solutions for a sustainable mobility system would require a broad perspective, by making connections to other sectors in society. That was why ‘land use policy’ was assessed to be important. Land use relates to whether the urban configuration is dense, scattered or mixed. From a sustainable perspective it is arguably better to build as densely as possible, because it requires less land and resources, while providing greater access for pedestrians to move around in the city.

Table 4. *Five identified dimensions and its respective states. To create some flexibility, "Means of transportation" can also refers to the main way of transportation, not excluding other modes of transport totally.*

#	Dimensions	State of Dimensions			
		I.	II.	IIII.	IV.
A.	*Means of transporation*	Air	Underground	Road & Sea	Virtual
B.	*Typ of fuel*	Hydrogen	Biofuel	Electric	Food
C.	*Land use policy*	Dense	Mixed	Scattered	-
D.	*Social policy*	Private mobility	Mixed	Shared mobility	-
E.	*Economic policy*	Taxes	Combined	Subsidies	-
F.	*Organisation*	Manual	Mixed	Autonomous	-

Four different solutions/internal scenarios were created based on the morphological method as illustrated in Table 4 below. Note that due to the number of dimensions and states as well as the limited scope of the study, there might be both attractive and feasible combinations (solutions) which have not been presented in this report.

Solution A involves using the road and sea as the main means of transportation. In essence, this implies cars, buses, trucks, snow mobiles, boats or any other vehicles that could be powered by biofuel. The use of land is scattered, and most people travel with private transportation options. The economic policy is combined, which means that taxes are put on vehicles using fossil fuels, while biofuel is being subsidized. Finally, people operate their vehicles manually.

Solution B also mainly involves transport on road and sea, but covers a potentially larger set of various vehicles that can be powered by electricity. In reality this includes cars, buses, trucks, tractors, snow mobiles, mopeds, scooters, bikes, pods, boats, trains and more. The land use policy is dense, which reduces distances within the city. Furthermore, people mainly use shared mobility services with vehicles that are driven autonomously by artificial intelligence. The combined economic policy implies that taxes are put on fossil fuels and subsidies are put on autonomous electronic mobility solutions.

Solution C differs from the previous two solutions in the sense that Virtual Reality (VR) has become a standard tool of communication, meaning that people do not need to travel physically back and forth from work or other social events. The city is built densely, and the thing that gets people active is healthy and nutritious food. In this scenario, people both own and share the digitized universe, and it is operated manually by groups and individuals. The economic policy means that digitized solutions have been subsidized, while taxes have been put on fossil fuels transport.

Solution D is also a bit different because it focuses on means of transportation in the air, i.e., airplanes, drones, and other smaller levitating vehicles powered by hydrogen, that can be used for transporting both people and goods. The land use policy is mixed, meaning that the built environment is both dense and scattered. People both have ownership and share the means of transportation, which is operated manually and autonomously. The economic policy implies that air transport has been subsidized and taxes have been put on fossil fuels transport.

Table 5. *Combined morphological table, with solution A (black), B (red), C (yellow), and D (purple). Note all possible combinations have not been tried, and other solutions might come to mind as well.*

#	Dimensions	State of Dimensions			
		I.	II.	IIII.	IV.
A.	*Means of transporation*	Air	Underground	Road & Sea	Virtual
B.	*Typ of fuel*	Hydrogen	Biofuel	Electric	Food
C.	*Land use policy*	Dense	Mixed	Scattered	-
D.	*Social policy*	Private mobility	Mixed	Shared mobility	-
E.	*Economic policy*	Taxes	Combined	Subsidies	-
F.	*Organisation*	Manual	Mixed	Autonomous	-

#	Dimensions	State of Dimensions			
		I.	II.	IIII.	IV.
A.	*Means of transporation*	Air	Underground	Road & Sea	Virtual
B.	*Typ of fuel*	Hydrogen	Biofuel	Electric	Food
C.	*Land use policy*	Dense	Mixed	Scattered	-
D.	*Social policy*	Private mobility	Mixed	Shared mobility	-
E.	*Economic policy*	Taxes	Combined	Subsidies	-
F.	*Organisation*	Manual	Mixed	Autonomous	-

#	Dimensions	State of Dimensions			
		I.	II.	IIII.	IV.
A.	*Means of transporation*	Air	Underground	Road & Sea	Virtual
B.	*Typ of fuel*	Hydrogen	Biofuel	Electric	Food
C.	*Land use policy*	Dense	Mixed	Scattered	-
D.	*Social policy*	Private mobility	Mixed	Shared mobility	-
E.	*Economic policy*	Taxes	Combined	Subsidies	-
F.	*Organisation*	Manual	Mixed	Autonomous	-

#	Dimensions	State of Dimensions			
		I.	II.	IIII.	IV.
A.	*Means of transporation*	Air	Underground	Road & Sea	Virtual
B.	*Typ of fuel*	Hydrogen	Biofuel	Electric	Food
C.	*Land use policy*	Dense	Mixed	Scattered	-
D.	*Social policy*	Private mobility	Mixed	Shared mobility	-
E.	*Economic policy*	Taxes	Combined	Subsidies	-
F.	*Organisation*	Manual	Mixed	Autonomous	-

3.10 Solution testing

Assessing the solutions based on each criteria led to the result being presented in Table 6. When evaluating compliance with the first criteria, accessibility, A and B score higher because both biofuel and electric battery vehicles have, more or less, already entered the current regime of mobility and will probably continue to develop. It is assumed that public transport will be powered extensively by these fuels and that access to an increasing number of various types of mobility will be offered. The reason why C scores lower is because VR constitutes the main means of (virtual) mobility and communication, and because it is unknown whether it can even be characterized as public transport. D scores lower based on the assumption that developing and using avian transportation powered by hydrogen will be more complicated, because it may take a long time to fulfill, and might also not be suitable in all cases (Office of EERE n.d).

With regards to the second criterion, safety, it was assumed that modes of transportation and design of pathways/roads would be of importance. Solution C scores the most points based on the fact that a large degree of accidents are prevented due to digitized services like VR, when people work and communicate from home. Providing digitized security is somewhat related to safety in this case, but still a bit outside the scope of this report's criteria. Furthermore, the densely built city environment favors pedestrians and perhaps also some lighter vehicles when needed. B got a slightly higher score than A based on the idea that autonomous vehicles will be safer than manually driven ones (NHTSA n.d). D got the lowest score, since air travel on a *larger scale* was assumed to become more unsafe compared to travel by road, even though it is known that road accidents are more common than plane accidents today (Ball 2014). Transportation of goods with drones may be more suited for this means of transport.

When assessing the environmental impact, B and D scored highest. This was mostly because both battery electric vehicles (BEVs) and vehicles powered by hydrogen fuel cells (HFCVs) can be considered as zero-emitting when it comes to greenhouse gasses and particles (EPA n.d). However,

this also assumes that the energy infrastructure in place to charge BEVs and to produce hydrogen for HFCVs will be clean and renewable. These vehicles will only be as environmentally sound as the energy that powers them. The reason why solution B scores slightly higher than D is related to the environmental policy being dense. It means that the city will be better at integrating green spaces, as well as becoming more walkable, and bringing people closer to workplaces and services which would decrease demand for public and private transport (WBCSD n.d).

Another factor, which makes B score high, is the shared mobility and autonomously operated mobility system. Although the science behind autonomous vehicles and its environmental impacts are ambiguous, studies have shown that in some cases it can reduce the number of miles on the road. If paired with mobility sharing services, autonomous vehicles could reduce the environmental impact by discouraging ownership and using software which plan the most efficient routes (Alexander-Kearns, Cassady & Peterson 2016). In effect, this would mean fewer vehicles on the road while also driving more efficiently.

The reason why C scores high as well is based on the fact that people would not need to travel as much to do their work and social activities. This means less transport overall which decreases environmental impact. However, developing a large-scale infrastructure based on VR would probably require more energy for cooling data centers which might then increase emissions (Energy Innovation 2020). The cold climate in Skellefteå, in combination with progress in energy efficiency, data storage technologies, and renewable energy would mitigate the environmental impact. Solution A got a lower score based on the assumption that biofuel might not be sustainable on a larger scale. It would probably require converting large areas of 'natural' forests into forests for industrial use, which will have a negative impact on biodiversity. However, looking into the potential of diverse sources of biofuel, like algae (Kumar et al. 2020) might ease the pressure on the Swedish forest.

Efficiency relates both to how interconnected the mobility system is, and how long it takes to travel. B scores higher based on the assumption that it would be relatively easy to integrate different modes of electric transportation, compared to that of hydrogen. C got a relatively high score since constructing and integrating VR-infrastructure might be less dependent on geographical locations compared to hubs for multipurpose transport. Furthermore, it might be more time efficient to work from home with a good internet connection than traveling to other places for work, social events etc. D scored lower based on the idea that it would be harder to create an integrated mobility system mainly based on air vehicles.

What can be mentioned for the last criteria, affordability, is that all solutions include a combined approach with taxes and subsidies. To make it simple, all solutions involve taxes on modes of mobility which use fossil fuels. The subsidies are designed to benefit respective solutions to make it more affordable to everyday citizens to use it. The assumption is also that investing in technologies like biofuel vehicles might be a bit cheaper, compared to hydrogen, since biofuel technologies are somewhat already part of the current regime while hydrogen is more on a niche experimental stage. Thus, it would require heavier investments for the municipality to develop a large-scale mobility system based on air vehicles and hydrogen than that of road/sea powered by biofuel.

Table 6. *Summarized result illustrating how each solution complies with the chosen criteria.*

Criteria	A.	B.	C.	D.
Accessibility	4	4	3	2,5
Safety	3	4	5	3,5
Environmental impact	3,5	5	4	5
Efficiency	3,5	4,5	4	3
Affordability	4	3,5	2,5	1
Average score	**3,6**	**4,2**	**3,7**	**3**

3.10.1 Robustness testing

The sensitivity analysis reveals that solution B copes better overall than the other solutions in the future scenarios (see Figure 2). C is very much dependent on a high degree of digital development, and D is highly dependent on the level of population growth. A copes somewhat better in a scenario of lower population growth and digital development, but could possibly be expanded a bit further in either direction.

Parts of solution A, C and D could very well be incorporated in solution B, e.g., the means of transportation, which would create a great diversity of mobility options and perhaps also better accessibility and efficiency. A trade-off might be that it would not be realistic to subsidize all the different solutions simultaneously, it would require some kind of prioritization. There is also a potential conflict between city planning to promote pedestrians and bikers or engine vehicles, and perhaps also between sharing transportation and the sense of freedom to use your own means of transportation. Furthermore, even though solution C fits well in the right area of the future board, it does not necessarily mean it is attractive to everyone in Skellefteå. It could be argued that coming out of a pandemic has left people craving for real physical interactions, which might make it harder to motivate why a highly digital solution would be a good option.

Figure 2. *Illustrates how well each solution (A=black, B=red, C=yellow, D=purple) fits into the external scenarios also being presented in Figure 1.*

3.11 Pathway

To create a pathway for the future vision a natural stage of the process is to investigate what changes are necessary. In Figure 3 some changes on a cultural level, a structural/institutional level, and a technological level are presented. Several changes can be discovered and more changes than those discussed in this report are probably necessary. Some of the changes will be described briefly in relation to the solutions from section 3.9 and discussed below.

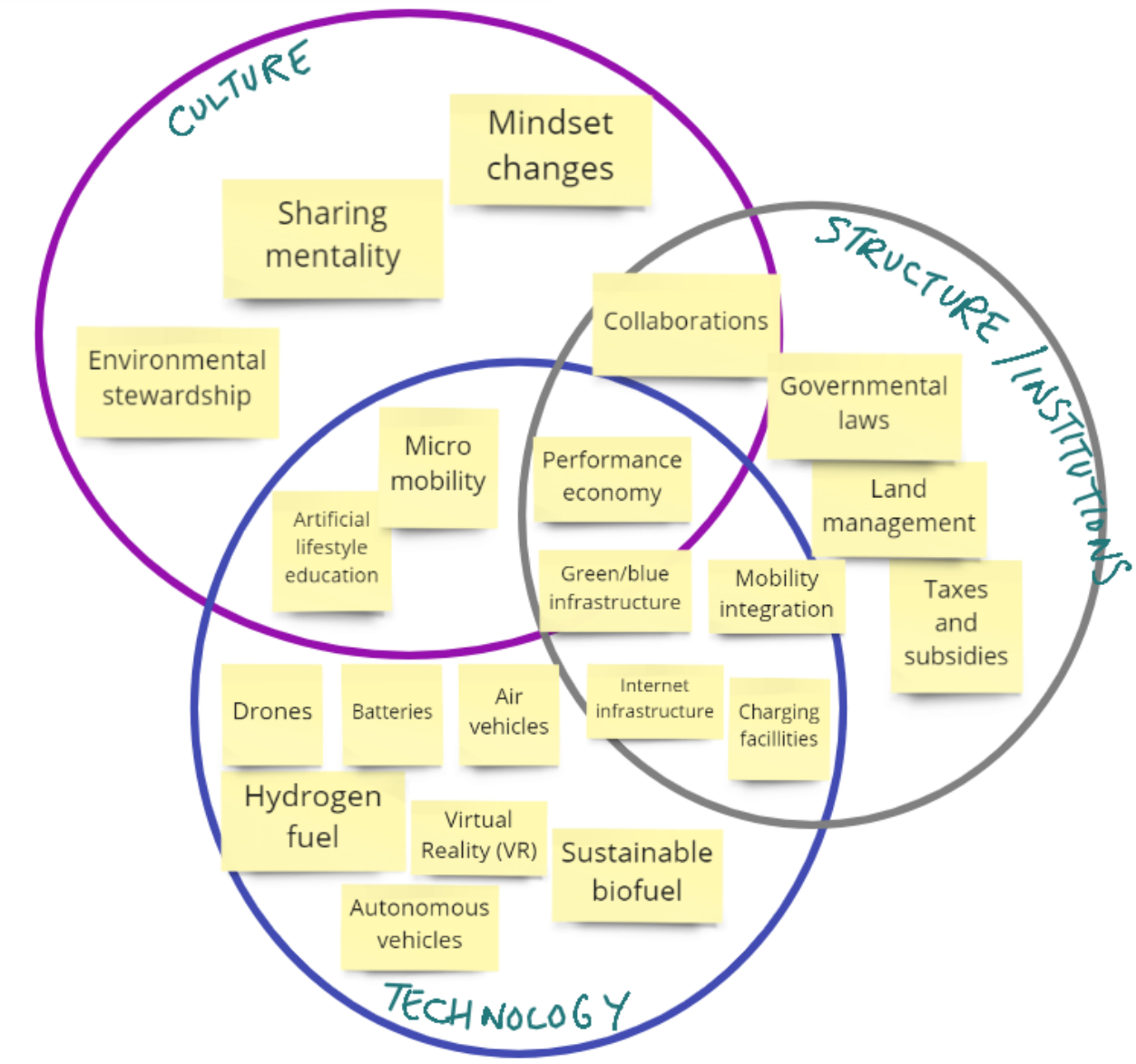


Figure 3. *Required changes in the mobility and transportation system on a cultural, structural and technological level*

Solution A needs few technical changes, many vehicles are already developed for biodiesel as fuel and since most of the mobility will be private there is not a need for too much infrastructure changes. However, a green infrastructure could be implemented to make the transport sector more

environmentally sustainable (Naturvårdsverket, n.d.), and wildlife crossings can be integrated into part of the mobility system to lower the impact on ecosystems and to combat habitat fragmentation (Trafikverket, 2022). Further, there is a need for sustainable biofuel and more research and projects are needed on 2nd generation biofuels based on for instance algae (Kumar et al., 2020). Further, since the land use is scattered and the vehicles are manually operated it would not require many behavioral changes for the citizens, since there will still be distances too far to walk or bike. However, if the only fuel allowed is biofuel governmental laws would need to change and this is unlikely to happen because of the already started initiative to electrify the Swedish car fleet (Regeringskansliet, n.d.). Lastly, the taxes for fossil fuels and subsidies for biofuel already somewhat exist (Regeringskansliet, 2021) but to have a real effect on the transport sector it probably must be intensified so that fossil fuels are not an option for anyone.

Solution B will require more changes than solution A, even though the transport is still mainly on road and sea the electrified car fleet requires changes in both infrastructure and technology. The green infrastructure is the same as in solution A but for this solution there is also a need for a change in the charging infrastructure. As mentioned in the introduction there is a widespread infrastructure for fossil fuel-based vehicles whilst the infrastructure for recharging of electric vehicles is still limited (Klitkou et al., 2015). Further, autonomous vehicles is a technology that needs to be developed more if it should be implemented in a daily life-society (Stockholm University, 2021). However, the changes needed for this solution are not just technical, more abstract mindset-changes are also needed. The cultural level in the transport sector covers peoples' attitudes towards transportation and if technologies such as autonomous vehicles are to be implemented and shared mobility will be the main option for transportation, attitudes must be changed and there is need for a "sharing is caring" mentality. For this solution to work it would also be preferable with mobility integration with hubs for transportation and mobility for instance since that could make collective transport easier to access.

Solution C requires changes in all three dimensions and the changes are quite large. Even though VR technology already exists and is already quite advanced it must be developed further if it should be implemented in an everyday life, both because of the software but also e.g., the comfortability of the hardware (Elmqaddem, 2019). The technology must be that good, so people don't feel the need to go and meet other people in person. This solution will need changes in education so that people can adapt to the new digital lifestyle, it requires changes in habits, and mentality. Since the city is dense people will still be able to walk and bike when they want to go to a supermarket, but all work and all travels can be done from home. On an institutional level an internet infrastructure must be built and it would probably require new laws and regulation if most peoples' life will be online.

Solution D might be the solution that requires most technical and institutional changes. For the entire transport sector to be airborne and powered by hydrogen the whole transport sector as we know it today must change and many new technologies must be implemented and developed. A hydrogen fueled, airborne transport sector also comes with a lot of uncertainties in costs and infrastructure problems (Hoelzen et al., 2022). There will be a need for changes in governmental laws since traffic rules and laws today are developed for land based traffic. It will require big changes in behavior and the city design and the changes would probably have to be on a national level rather than in the municipality of Skellefteå alone. Technology for flying vehicles exists, and the first flying car has got the permission to fly in Europe. However, it is very expensive technology and a pilot certificate is required (Efter fem, 2022, 3:09) and the technology needs to be further developed to be used on a broad level.

For all four solutions some changes are needed in all three dimensions. There are probably more changes needed and it is hard to evaluate how effective a certain change might be. One could argue that it might be better to invest in already existing infrastructure and techniques since the changes need to happen fast and it could be expensive and resource consuming to do many huge changes at the same time. Therefore, solution C and D might not be the right path if only one solution is to be implemented. However, it could also be a too narrow path to invest in only existing technologies since this contributes to the already existing lock-in. The lock-in in the transport system makes it uncertain to invest in new technologies since a lock-in system leads to an economic advantage for investments in what already dominates the market. It is more economically viable to do smaller follow-up investments in the dominant design than larger initial investments in new products since there is no guarantee that the new product will succeed on the market (Klitkou et al., 2015). Therefore, if new innovations and new technologies are to be implemented, there are more challenges and changes that need to be done. However, there is potential in new technologies, such as drones, that could contribute to a more sustainable society (Merkert and Bushell 2020) therefore a combination of several or all solutions would be preferable.

Whether or not the changes in the transport sector in Skellefteå means that existing technologies are going to be used or if new technologies will be implemented, several changes must be made in the society. The suggested pathway is shown below in Figure 4. The first step will be the top-down approaches, the initiative must come from the governmental side and a clear plan for sustainable infrastructure must be conducted. Necessary laws, taxes, and subsidies should be implemented as soon as possible, and more research is needed to get a clear understanding of what changes are most likely to have a positive effect. It is also important to actively create an attitude change in the society and this requires communication and value initiatives. To reach as many as possible it is important to expose citizens to information about shared mobility, the benefits, and how it can be used. Some examples of how to reach a broader audience is to use social media and influencers, to hold workshops, and to do commercial campaigns. All this is suggested since it takes time to change behaviors and the transition could move faster if citizens are motivated to be involved in the change rather than if it is just an initiative from the municipality. However, target groups respond differently to motivators, e.g., some might respond to price and for some it is enough to know what consequences your behavior has on the environment.

Therefore, more information is required but it could also be good to initiate a campaign where people can travel nine times and get the tenth for free when using collective transportation or shared mobility services. Further down the pathway, closer to 2050 the actions become increasingly abstract, and it becomes difficult to say what actions have the greatest impact to reach the vision for 2050. An assumption is that using fossil fuels in vehicles will probably be highly restricted after 2030 and it is possible that autonomous vehicles will become common. If the changes in attitudes towards a more shared way of living is implemented, shared mobility will be the new norm and less people will own their vehicles. Furthermore, closer to 2050 a performance economy might be in place and people feel like they are an integral part of the natural ecosystem. However, what exactly is required to reach this in barely 30 years is very hard to determine, but one of the general approaches would be to work with initiatives that focus on changing people's attitudes towards mobility.

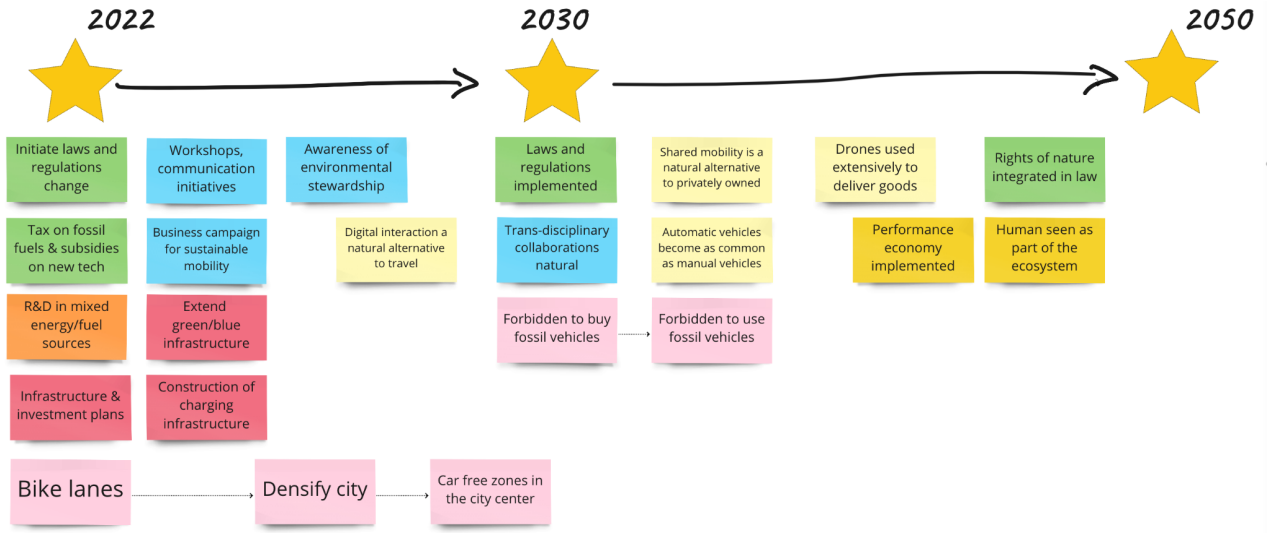


Figure 4. *Pathway for changes from the year 2022 until 2050. Illustrating what needs to start/has been accomplished at certain points in time.*

3.12 Follow-up experiments

Further modules in the mPB framework are Action Plan and Follow-ups, these modules will not be covered in this report. Instead, five different experiments are described along with their supporting structures that facilitate learning and ensure synergies between the different experiments.

Most of today's technology is stuck in various lock-ins. The use of electricity in homes has been a part of everyday life in Sweden for a long time. Ever since the 1960s, people have been accustomed to basic home functions being powered by electricity (Vattenfall, n.d.). However, electricity as a vehicle fuel source has not been as obvious. Surveys show that there is a high level of uncertainty using electricity as a vehicle fuel due to a lack of knowledge, people would rather use fuels that they know will work (Tesla Club Sweden, 2019). The Covid-19 pandemic changed people's behavior regarding transportation and social contexts. Due to the restrictions that existed in Sweden during the pandemic, people's use of public transport has decreased, and when travel is needed, car or walking has become the priority (WSP, 2021). The pandemic has also increased the amount of people working from home. WSP (2021) also mentions in their study that the habits, regarding reduced number of trips, may persist.

Black swan events and discontinuities can be contributing elements in changing the socio-technical configuration. In this project, discontinuities such as the emergence of higher electricity prices and rising prices on materials used in battery production due to a re-shaped economy, lower supply of rare earth materials and the solution of fusion power have been discussed. These are factors that may affect the development of electric mobility, as higher electricity prices put the economic sustainability under scrutiny, whereas new technologies such as fusion power would reduce the need for electricity coming from other sources of energy. Black swan events that have been discussed during the project are war scenarios, which affects both infrastructure and the ability to produce energy. Today the world' energy supply is affected by the ongoing war in Ukraine. It is mainly gas supplies that are affected, which in turn has the effect of increasing electricity consumption (Tidningen Energi, 2022). The Covid-19 pandemic has affected the supply of materials to Sweden and a new pandemic would probably affect people's travel patterns more than ever. It could also lead to an economic crisis and contribute to fewer

people moving to Sweden and Skellefteå. A sudden closure of Northvolt would leave many people unemployed and contribute to a personal black swan event. This could lead to people moving from Skellefteå due to lack of jobs.

The system that connects the different experiments consists of reducing fossil fuel cars, increasing car sharing, safe technology, accessibility for all in public transport, economic sustainability and reducing environmental impact. These factors are inspired by the criteria mentioned earlier in the report.

Experiment 1: Optimizing travel payment
To create a sustainable transport system, a simple and well-functioning payment system is needed. Experiment 1 focuses on finding the best approach to optimize travel for as many people as possible. The aim is to increase accessibility, affordability, and efficiency of travel. In Skellefteå today, tickets for the city's buses can be bought via an app, through the online shop or directly on the bus (Skellefteå buss, n.d.). It is possible to refill the bus card with any amount of money, where one ticket lasts for 60 minutes, or to buy 6 to 40 tickets valid for a specific route and thereby receive a discounted price.

A common platform for ticket purchase would facilitate the travelers experience. It is worth noting that not everyone has access to a smartphone. What should be investigated is how travel patterns change when using a credit card to purchase tickets. Is it mainly long or short trips? Changing the ticket price to a single price and reducing the cost of the ticket could generate more passengers. However, if the majority of the population travels through several transfers, unit pricing may contribute to reduced usage as the price of the total trip is likely to be more expensive than today. Another option is to pay according to the length of the journey. However, this would require checking in and out of public transport.

What is needed in this experiment are researchers, companies that make it possible to implement the system, and users who can try out the experiment and thus contribute with statistics. The experiment should first be implemented in the already existing public transport system in Skellefteå, where unit pricing should be the first change. Experiment 1 is technology driven but also involves governance, as public transport deals with both private and state-owned companies. Support structures for implementing experiments include advertising the new public transport system via social media and ambassadors who can help create a positive mindset. Experimentation 1 should include all users of public transport to contribute with their knowledge and insights.

Experiment 2: Urban model simulation
One of the aforementioned solutions deals with the choice of a dense or scattered community. What Experiment 2 aims to do is to develop a model simulation to investigate how the traffic flow in Skellefteå will be affected depending on how dense the city is. The experiment helps to understand how traffic safety changes in relation to how concentrated the city is, as well as how efficiency and the amount of greenhouse gas emissions are affected. A program that has the potential to be useful in this case is the Multi-Agent Transport Simulation (MATSim) tool. This tool can consider differences in people's activities, choice of transport type, different time periods, and different route choices (Simoni et al. 2018).

MATSim can also serve to evaluate which type of charging is most suitable for the use of vehicles in Skellefteå (Simoni et al. 2018). The ultimate method would possibly be to measure the specific emissions of each vehicle. Implementing technology for each car's individual emissions is currently economically unsustainable because the technology is not currently available and the installation that

would need to be done in each car would be expensive (Feng et al. 2013). Experiment 2 can therefore be used to decide how to charge for the road network, for example by miles driven or by dividing the city into different environmental zones to reduce environmental pollution.

Experiment 2 is a technical proposal that mainly involves researchers and developers who can manage the MATSim program, but the experiment can also be used for governance. Depending on the results, the choice of a dense or dispersed city could be encouraged. This result can be used as a basis for further planning and development in Skellefteå. Supporting structures are the participation of the municipality in the simulation process. There is also a need for people to analyze the results of the simulation in order to apply them in reality and contribute to decisions on a national level.

Experiment 3: Living lab, testing drones

The anticipated rapid population growth in Skellefteå will increase the consumption of goods. In order to develop Skellefteå's transport and supply system in a sustainable way, a number of experiments can be done. The main subject of discussion in this project is how the implementation of drones would simplify and reduce the environmental impact of the delivery of goods. Experiment 3 aims to reduce the number of (heavy) truck vehicles in Skellefteå, thereby reducing greenhouse gas emissions and contributing to a safer transport system, by releasing space on the street level for pedestrians.

Today, the delivery and distribution of goods is mainly done by vehicles equipped with internal combustion engines. This contributes both to traffic congestion, greenhouse gas emissions and increases the risk of being injured in traffic (Pugliese, 2020). Goods are delivered to Skellefteå mainly through the Port of Skellefteå, railway or by trucks (Port of Skellefteå, n.d.). Development of drones for a more sustainable delivery process is already taking place but experiment 3 provides an opportunity for creating a living lab in Skellefteå. This living lab can in cooperation with researchers and companies test how a delivery process consisting of a central distribution hub followed by distribution by drones would work in reality. Supporting structures to make implementation possible are the need for researchers who can continuously develop the technology, users in the form of private individuals but also companies, and a platform that clearly describes the process but also makes it possible to request the service for private use.

The experiment, which is of a technical nature, provides an opportunity to investigate and develop the technology required to use drones as distribution vehicles. However, several technical details should be carefully examined, such as the capacity and efficiency of a delivery process using drones. Determining the legal requirements for drone operations would also be required.

Experiment 4: A virtual world

In recent years, an increasingly digital world has opened up to society. The Covid-19 pandemic has contributed to the fact that many people are working from home. Around 40% of Sweden's working population between the ages of 15 and 74 were working from home in the first months of 2021 (SCB, 2021). Experiment 4 aims to investigate how a virtual world would affect working from home and engaging socially. A successful virtual world could contribute to a reduction of work-related travel and create safer transport use due to fewer vehicles in the municipality. In addition, fewer trips would reduce the amount of pollution and pressure on ecosystems.

In a virtual world, an avatar would be created to represent a person. By using this method, a more reality-based everyday life can be experienced and a workday away from home will feel more like a day at the office (Frontiers, 2018). For the implementation of this experiment, developers of software that enable avatar creation and world building are needed. Companies, together with their staff, will

be necessary to carry out the experiment. Supporting structures are education of the staff, to understand and master the virtual life. In addition to education, software is needed to enable the interconnection of different companies and their avatars. This experiment is of a technical nature but incorporates social culture as it gives rise to a new way of everyday life.

Experiment 5 - Optimizing shared worker travel

Given the rapid population growth and the increased need to travel to work, Experiment 5 aims to optimize commuting for employees. The experiment involves a collaboration between companies, where the business model promotes a performance economy. The idea is for companies to use a shared means of transport that allows employees within the company to travel to work together. A shared transportation system results in fewer vehicles on the road and a lower amount of pollution . The ambition is that shared transport would increase the accessibility of communication to the workplace and simplify travel. The nature of the experiment may vary depending on the size of the company but is based on vehicle sharing, either by pick-up or by carpooling. The goal is to reduce the number of owned vehicles and increase accessibility for travelers.

The performance economy in this case provides benefits to the user in terms of not owning their own car and still being able to get to and from work in a convenient way. The business model of the companies conducting the experiment is based on offering their employees added value in the form of accessible transport. This business model should be appealing to both the company offering the service and the company hired to provide it. Support structures needed to implement the experiment are incentives for companies to consider a change in their business model. A change requires time and effort which in turn requires money. If companies do not benefit from the change, it will be difficult to implement the experiment.

4 Discussion and Conclusions

4.1 The modules and mPB process

The time span from the project initiation to the submission of the completed report is approximately eight weeks. Although identifying stakeholders did not pose a big challenge, with frequent collaboration and input of opinions from stakeholders not being possible in such a short period of time, in the early stages, defining an appropriate and specific topic was somewhat difficult due to the limited previous knowledge about Skellefteå and the openness of the project. The group managed to find a direction and an approach which all members were content with, and defining the problem orientation and the current situation were relatively simple after having a clear direction.

While progressing along with the mPB process, the group found it difficult when changes were made to redo previously completed modules and exercises due to time constraint. Considerable efforts have been made to understand the uncertain elements of the mPB process related to project outcome and to make the different modules coherent with each other in the defined problems.

Challenges that occurred during specific modules are mainly related to the future vision and the solutions. If more time had been available, the vision could have been refined and incorporated the keywords of sustainability more clearly. It was also difficult to formulate ideas that are realistic but original that have not yet been implemented by the Slellefteå municipality because the project has been based largely on data collection and analysis.

During the process of developing the criteria, we initially had difficulties in specifying and inter-linking the selected criteria. This made us go back to the problem orientation and question the chosen system boundary. We decided to move from a broad city-level perspective to reformulate the problem and focus on mobility. This decision forced us to change the first seven modules. The group started very broadly with the project (divergence) and then narrowed down our focus on mobility during the mPB process (convergence). When mobility was chosen, we somewhat diverged again, taking a broader perspective on what other areas might be connected to mobility (e.g., the built environment, digitalisation, culture and values). The process was time-consuming and contributed to repetitions of further modules being carried out in a hurry. Despite the time pressure, the iterative nature of the mPB process allowed us to go back and forth to change or update the content. The modules we have returned to and modified the most are the Criteria, Solution testing and Pathway.

The data collection did, in many cases, come after reasoning and discussion among the group members. This gave great insights along the way in all the modules since new information constantly appeared but it did not hinder or narrow the creative thinking along the way to what already exists and what is actually possible to implement. Insights from the data from the Q&A and semi structured interview were mainly integrated in Problem orientation, Current situation analysis, and Needs and function and worked as a good insight from two stakeholders that are closely connected. The first Q&A session with the municipality gave insight into what the different challenges were (mobility being one) and what the current situation looks like in Skellefteå. The semi structured interview also provided great information about this, and also some of the needs of people living there.

4.2 Limitations and recommendations for further exploration

The limitations of the report include a time frame of eight weeks and two Q&A sessions with the municipality of Skellefteå. The time frame has contributed to each module being covered in a short period of time. This in turn may have led to rushed decisions and unreliable results. If more time had been available, the iterative nature of the mPB process could have been further exploited. More time could also have improved the stakeholder analysis and the variety of stakeholders that we have interacted with. More stakeholder analysis would have provided a broader perspective on the impact of the mobility system in the municipality of Skellefteå.

For future exploration of the mobility system and its impact on the community in Skellefteå, the Action Plan and Follow-ups modules should be explored further. This includes a detailed performance test of the action plan with different deadlines, listing specific steps and tasks, and describing how selected experiments will be monitored and measured. Creating a mixed experiment rooted in all solutions could also be created. Inviting more potential stakeholders for collaborations is also an option.

4.3 Conclusions

- Solutions should be combined and a combination of technical, social and institutional changes are needed.
- All solutions are carried out to provide evidence of how the different solutions, together or individually, are suitable in Skellefteå. The experiments investigate the reduction of fossil fuels, increasing car sharing, safe technology, accessibility, economic sustainability and reducing environmental impact.
- Participatory collaborations between stakeholders are essential in accomplishing a sustainable transition in the mobility system of Skellefteå.

5. Description of a teamwork

During the project, the team has mainly used Zoom and Miro software to communicate and for co-working. Each week the group has participated in seminars for collaborative work and in addition to this individual work has been carried out. The mPB concept has been followed and each module has been discussed together. After this, each person has been given individual responsibility for including discussed material in the report.

References

Alexander-Kearns, Cassady and Peterson. 2016. The Impact of Vehicle Automation on Carbon Emissions. [Accessed 11 March 2022]. https://www.americanprogress.org/article/the-impact-of-vehicle-automation-on-carbon-emissions-where-uncertainty-lies/

Avelino, F and Wittmayer, J.M 2016. Shifting power relations in sustainability transitions: a multi-actor perspective. *Journal of Environmental Policy & Planning,* 18(5), pp.628-649[Accessed 13 March 2022]. https://www.sciencedirect.com/science/article/pii/S2210422416301009

Ball, J. 2014. The Guardian. *How safe is air travel really?* [Accessed 15 March 2022] https://www.theguardian.com/commentisfree/2014/jul/24/avoid-air-travel-mh17-math-risk-guide

Bodo, T. 2019. Rapid urbanization: theories, causes, consequences and coping strategies. *Annals of Geographical Studies*. 2(3). 32-45.

Dóci, G. 2022. *The revolution of niches - The socio-technical transitions.* [Lecture]. [Accessed January 20]

Efter fem. 2022. TV4. [TV-show] [Accessed 16 March 2022] https://www.tv4play.se/program/efter-fem/flygande-bilar-godk%C3%A4nda-nu-f%C3%A5r-de-k%C3%B6ra-i-europa/13744416

Elbilsstatistik. n.d. *SVERIGES NATIONELLA STATISTIK FÖR ELBILAR OCH LADDINFRASTRUKTUR.* [Accessed 7 March] https://www.elbilsstatistik.se/

Elmqaddem, N. 2019. Augmented reality and virtual reality in education. Myth or reality? *International journal of emerging technologies in learning*. 14(3). https://doi.org/10.3991/ijet.v14i03.9289

Energy Innovation Policy and Technology LLC. 2020. *How much energy does data centers really use?* [Accessed 11 March]. https://energyinnovation.org/2020/03/17/how-much-energy-do-data-centers-really-use/

Feng, Y., Fullerton, D. and Gan, L. 2013. *Vehicle choices, miles driven, and pollution policies*. Springer Link. [Accessed 16 March 2022] https://link.springer.com/article/10.1007/s11149-013-9221-z

Frontiers in Robotics and AI. 2018. Avatar Embodiment Towards a Standardized Questionnaire. [Accessed 16 March 2022] https://www.frontiersin.org/articles/10.3389/frobt.2018.00074/full

Hoelzen, J., Silberhorn, D., Zill, T., Bensmann, B. and Hanke-Rauschenbach, R. 2021. Hydrogen-powered aviation and its reliance on green hydrogen infrastructure–Review and research gaps. *International Journal of Hydrogen Energy*. 47(5): 3108-3130 https://doi.org/10.1016/j.ijhydene.2021.10.239

Holmström, C., 2022. Petrol tax. Ekonomifakta, [online]. [Accessed 17 March 2022] https://www.ekonomifakta.se/Fakta/Energi/Styrmedel/Konsumtionsskatter-pa-bensin/

Johansson, P and Ulander, G.; representatives from the Skellefteå municipality. 2022. Q&A Session with Skellefteå municipality (part 1) 10 February.

Klitkou, A., Bolwig, S., Hansen, T. and Wessberg, N. 2015. The role of lock-in mechanisms in transition processes: The case of energy for road transport. *Environmental Innovation and Societal Transitions*. *16*: 22-37. https://doi.org/10.1016/j.eist.2015.07.005

Kumar, M., Sun, Y., Rathour, R., Pandey, A., Thakur, I. S., and Tsang, D. C. 2020. Algae as potential feedstock for the production of biofuels and value-added products: Opportunities and challenges. *Science of the Total Environment*. 716. https://doi.org/10.1016/j.scitotenv.2020.137116

Lo, Y. and Lu, Y.; Northvolt employee and her partner. 2022. Semi-structured interview about Skellefteå 18 February.

Merkert, R., and Bushell, J. 2020. Managing the drone revolution: A systematic literature review into the current use of airborne drones and future strategic directions for their effective control. *Journal of Air Transport Management*. 89. https://doi.org/10.1016/j.jairtraman.2020.101929

mPB. n.d. *Modular Participatory Backcasting.* [Accessed 7 March] http://mpb.urbant.org

National Highway Traffic Safety Administration (NHTSA). N.d. *Automated Vehicles for Safety. The Topic: Benefits/Safety.* [Accessed 15 March] https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

Naturvårdsverket. n.d. *Grön infrastruktur.* [Accessed 16 March] https://www.naturvardsverket.se/gron-infrastruktur

Nykvist, B., and Nilsson, M. 2015. The EV paradox–A multilevel study of why Stockholm is not a leader in electric vehicles. *Environmental Innovation and Societal Transitions*. *14*, 26-44. https://doi.org/10.1016/j.eist.2014.06.003

Office of Energy Efficiency & Renewable Energy (EERE). N.d. *Hydrogen Storage Challenges.* Hydrogen and Fuel Cell Technologies Office. [Accessed 15 March]. https://www.energy.gov/eere/fuelcells/hydrogen-storage-challenges

Pereverza, K., Pasichnyi, O. and Kordas O. 2018. *Modular participatory backcasting: A unifying framework for strategic planning in the heating sector.* ScienceDirect. [Accessed 7 March] https://www.sciencedirect.com/science/article/pii/S0301421518306402?via%3Dihub

Port of Skellefteå. n.d. OM PORT OF SKELLEFTEÅ. [Accessed 16 March] https://portofskelleftea.se/om-port-of-skelleftea/

Pugliese, L.D.P., Guerriero, F. and Macrina, G. 2020. *Using drones for parcels delivery process*. ScienceDirect. [Accessed 16 March 2022] https://www.sciencedirect.com/science/article/pii/S2351978920305928

Purvis, B., Mao, Y. and Robinson, D. 2019. Three pillars of sustainability: in search of conceptual origins. *Sustainability science*. *14(3):* 681-695. https://doi.org/10.1007/s11625-018-0627-5

Regeringskansliet. n.d. *Transportsektorn elektrifieras*. [Accessed 7 March 2022] https://www.regeringen.se/regeringens-politik/transportsektorn-elektrifieras/

Regeringskansliet. 2021. *Klart med fortsatt skattebefrielse för flytande biodrivmedel.* [Accessed 16 March 2022] https://www.regeringen.se/pressmeddelanden/2021/09/klart-med-fortsatt-skattebefrielse-for-flytande-biodrivmedel/

SCB Statistikmyndigheten. 2021. *Allt fler arbetar hemifrån*. [Accessed 16 March 2022] https://www.scb.se/pressmeddelande/allt-fler-arbetar-hemifran/

Sharifi, A. 2021. Urban sustainability assessment: An overview and bibliometric analysis. *Ecological Indicators*. 121. https://doi.org/10.1016/j.ecolind.2020.107102

Simoni M.D., Kockelman, K.M., Gurumurthy, K.M. and Bischoff, J. 2018. Congestion pricing in a world of self-driving vehicles: An analysis of different strategies in alternative future scenarios. ScienceDirect. [Accessed 16 March 2022] https://www.sciencedirect.com/science/article/pii/S0968090X1830370X

Skellefteå buss. n.d. *Biljetter & priser nytt 1 dec 2021*. [Accessed 16 March 2022] https://www.skebuss.se/biljetter-priser-nytt-1-dec-2021/

Skellefteå municipality. n.d.a. På god väg mot 2030. [Accessed 23 February 2022] https://skelleftea.se/2030/startsida/

Skellefteå municipality. n.d.b. *När Skellefteå förändras hänger allt ihop.* https://skelleftea.se/2030/startsida/resultat-av-medborgardialog

Skellefteå municipality. n.d.c. *Hållbarhetsstrategi för Visit Skellefteå*. [Accessed 16 March 2022] https://www.visitskelleftea.se/media/2103/hallbarhetsstrategi_visit-skelleftea.pdf

Skellefteå municipality. 2020. *Trafikprogram*. [Accessed 15 March 2022] https://skelleftea.se/download/18.46061409177d7ef93035eb51/1616048726547/F%C3%96P_Skelleftedalen_Trafikprogram_bilaga_2020_Antagen.pdf

Skellefteå municipality. 2022a. *Busstrafiken*. [Accessed 23 February 2022] https://skelleftea.se/invanare/startsida/bo-trafik-och-miljo/resor-och-transporter/busstrafiken

Skellefteå municipality. 2022b. *Cykla.* [Accessed 23 February 2022] https://skelleftea.se/invanare/startsida/bo-trafik-och-miljo/resor-och-transporter/cykla

Sodiq, A., Baloch, A. A., Khan, S. A., Sezer, N., Mahmoud, S., Jama, M. and Abdelaal, A. 2019. Towards modern sustainable cities: Review of sustainability principles and trends. *Journal of Cleaner Production*. 227: 972-1001. https://doi.org/10.1016/j.jclepro.2019.04.106

Stockholm University, 2021.*Självkörande bilar fixar inte det sociala samspelet.* [Accessed 16 March 2022] https://www.forskning.se/2021/10/08/sjalvkorande-bilar-drojer/

Tesla Club Sweden. 2019. *Fler vill köpa elbil - men vågar inte*. [Accessed 10 March 2022] https://teslaclubsweden.se/fler-vill-kopa-elbil-men-vagar-inte/

Tidningen Energi. 2022. *Så påverkar Ukrainakriget energimarknaden*. [Accessed 15 March 2022] https://www.energi.se/artiklar/2022/februari-2022/sa-paverkar-ukrainakriget-energimarknaden/

Trafikverket. 2022. *Miljöarbetet i Tvärförbindelse Södertörn*. [Accessed 16 March 2022] https://www.trafikverket.se/nara-dig/Stockholm/vi-bygger-och-forbattrar/Tvarforbindelse-Sodertorn/Miljo/

Ulander, G.; representative from the Skellefteå municipality. 2022. Q&A Session with Skellefteå municipality (part 1) 3 March.

United Nations. n.d.a. *THE 17 GOALS*. [Accessed 10 March 2022] https://sdgs.un.org/goals

United Nations. n.d.b. *11 Make cities and human settlements inclusive, safe, resilient and sustainable*. [Accessed 10 March 2022] https://sdgs.un.org/goals/goal11

United States Environmental Protection Agency (EPA). N.d. *Hydrogen Fuel Cell Vehicles.* [Accessed 11 March 2022]. https://www.epa.gov/greenvehicles/hydrogen-fuel-cell-vehicles

Universal Pictures UK. 2020. *Fast & Furious 9 – Official Trailer (Universal Pictures) HD.* [Video]. [Accessed 13 February 2022] https://www.youtube.com/watch?v=FUK2kdPsBws

Vattenfall. n.d. *Elen ändrade folks vardag*. [Accessed 10 March 2022] https://historia.vattenfall.se/stories/en-ny-vardag-med-el/elen-andrade-folks-vardag

Volvo Car Sverige. 2014. *Volvo XC70 feat. Zlatan - Made by Sweden.* [Video]. [Accessed 13 February 2022] https://www.youtube.com/watch?v=cbvdzQ7uVPc

World Business Council for Sustainable Development. N.d. *Can dense cities save the planet?* [Accessed 15 mars] https://www.wbcsd.org/Programs/Cities-and-Mobility/News/Can-dense-cities-save-the-planet

WSP. 2021. *WSPs stora mobilitetsstudie 2021*. [Accessed 10 March 2022] https://www.wsp.com/sv-SE/insikter/wsps-stora-mobilitetsstudie-2021

Zhao, X., Ke, Y., Zuo, J., Xiong, W., & Wu, P. 2020. Evaluation of sustainable transport research in 2000–2019. *Journal of Cleaner Production*. 256. https://doi.org/10.1016/j.jclepro.2020.120404