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Hyperloop in Northern Europe
A possibility for logistic sustainability

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Abstract

The thesis aimed to study the possibility of a hyperloop system and its possible benefits in Northern Europe, while looking at methods for increasing sustainability of logistics among the Northern countries of Europe i.e. Sweden, Denmark and Finland. Main objectives were to study a possible solution to many of the growing issues that are rising alongside the digitalization of society and the development of logistics, what was contributing to the rise of emissions and prolonged supply chain lead times and how they could be mitigated. Additionally, this paper looks at set objectives for decarbonisation in the area and the possibility of utilizing sustainable sources of energy and already available infrastructure.

This thesis is a qualitative research and utilized comparative and observational research methods aimed at future technology.

Based on this thesis it is possible to understand what hyperloop technology is, how it could affect sustainability and develop logistics towards supply chain optimization and decarbonisation. To some extent, this paper also explains alternative ways of green energy and on how self-sufficient systems can be implemented.

The conclusion of this study shows that there is still much-needed development in the technology itself before hyperloop could be a viable substitute for aviation, railway and road transportation. With the Covid-19 effect, much uncertainty exists around what future transportation will look like and how far the impact extends on both economics and society.

Theoretically, improvements to logistics and sustainability can be achieved by utilizing the current infrastructure while implementing a hyperloop system that uses alternative energy sources. Reduced need for road transportation and ocean freight will reduce pressure on sustainability as a whole, while shortening lead times and optimization within the supply chain.

Keywords

hyperloop, innovation, transportation, sustainability science

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NOMENCLATURE

BOEM – Bureau of Ocean Energy Management

GHG – Greenhouse Gas

Hydrokinetic – Force transmitted by the motion of fluids

KW – Kilo Watt

LSP – Logistic Service Provider

Maglev – Magnetic Levitation

Multimodal – Transportation method consisting of two or more ways of transporting a unit

MW– Mega Watt

SDG – Sustainable Development Goal

TRL – Technological Readiness Level

UN – United Nations

1 INTRODUCTION

By studying related literature and reports involving sustainability and the concepts of hyperloop technology, it became clear that traditional logistic solutions are not optimal, if we are to improve sustainability, lead times and quality in the supply chain. Not only are greenhouse gas emissions the only unwanted by-product from transportation, implications to other areas in sustainability can be just as damaging.

This paper studied how this near-future alternative in transportation technology could be a benefit to both sustainability and transportation. In order to develop a sustainable future in transportation, technological development must be assessed and supported.

Hyperloop was introduced in 2013 with the Hyperloop Alpha white paper, written by Elon Musk, the entrepreneur and founder of companies such as PayPal, Tesla and SpaceX. This concept consists of passenger capsules travelling inside tubes with a close to vacuum atmosphere (1/1000th of atmospheric pressure) while levitating on air bearings to reduce friction (figure 1). Because of this, the pods can reach speeds up to 1220km/h. (MIT Hyperloop 2017, 16.)

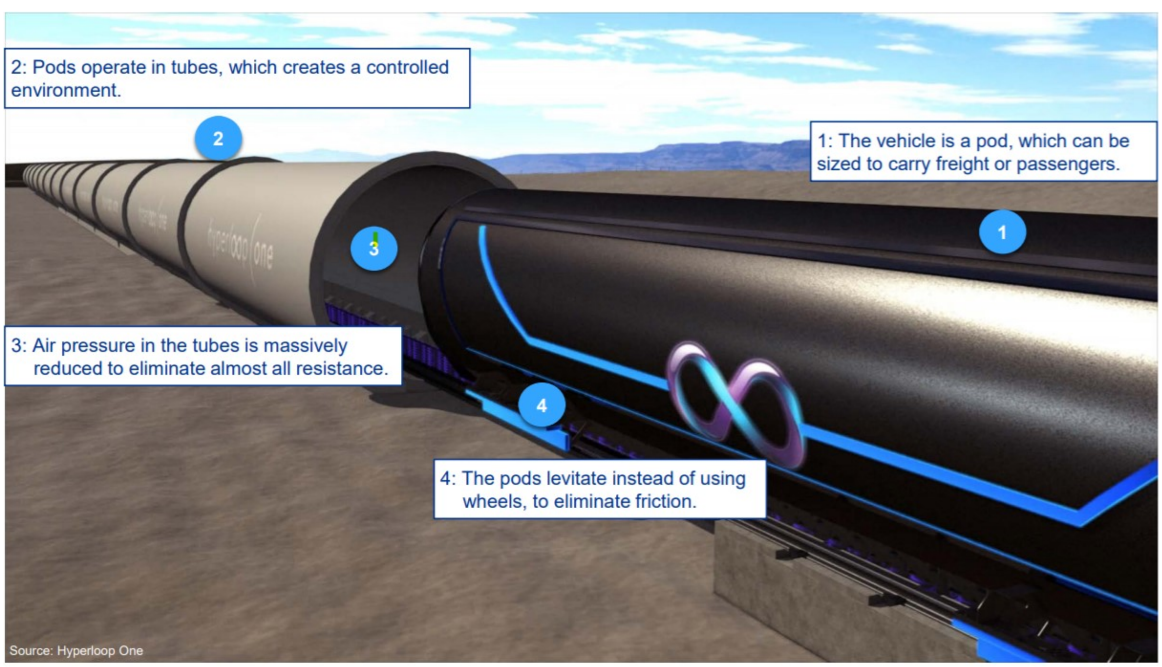


Figure 1. Hyperloop system (Hyperloop one 2016).

The hyperloop technology is a concept alternative for travelling short to middle ranged distances (up to 1500km) while being cheaper, faster and more sustainable than other options, such as aviation or high-speed rails. As a new system, it could be the fifth alternative for transportation which supports previous solutions, cars, trains, planes and boats. (Musk 2013, 2.)

The Hyperloop system comprising all infrastructure, mechanical, electrical, and software components are designed for reliability, durability, and fault tolerance over a service life of 100 years, while maintaining safety levels that match or exceed the safety standard of commercial air transportation (Musk 2013, 56).

This study was written between March 2019 - September 2020 when hyperloop technology and sustainability awareness were developing and growing rapidly. As this concept technology has started a new type of “space race” for developers to be the first one succeeding in creating a viable commercial system, awareness of all risks and factors involved needs to be assessed.

2 THEORETICAL FRAMEWORK AND RESEARCH METHODS

In Northern Europe, many retailers have their base distribution warehouse located in Sweden. This grows lead times from instant availability (if products are available domestically) to up to several weeks, when they have to be ordered from abroad. Based on studies, 59% of customers have stated that 3-5 business days for the delivery is expected. (Postnord, 2019).

This forces several end consumers to decide whether to switch from the desired brand or retailer to a different one, or not buy the product at all. Customers will also be exposed to the risk of receiving wrong or damaged goods, which would reset the process and additionally create a separate return process.

The effects from these transportations multiply for every country taken into consideration. In 2018, 29% of all online shopping was made from outside the

Northern countries. Finns in particular ordered 38% of all goods from abroad (figure 2). The total for online shoppers in Europe was 286 million consumers, totalling €235m. Also, 217 million consumers ordered from abroad. (Postnord, 2019).

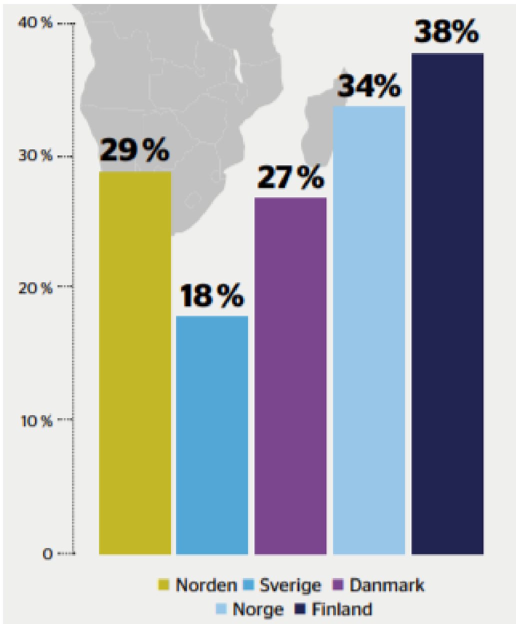


Figure 2. Online shopping from abroad (Postnord 2019).

Nordic consumers shopped online for SEK 230.2 billion (€23.02 billion) in 2018, while ten years ago it was around SEK 73 billion (€7.26 billion). (Postnord, 2019).

In the European Commission, many decisions and policies are working towards improving and updating ageing transportation networks as the objective is to reach net-zero emissions by 2050. To achieve this, all transport modes should contribute to decarbonisation. Global commitments for alternative fuels and smarter infrastructures alongside a systematic increase in zero-emission vehicles, rail network capacity and the utilization of digitalization, transportation system efficiency improves. All driven by innovation and investments. (Bulc 2018.)

Currently LSPs are struggling to balance how they meet the increased workload with the increased demand for sustainability, while staying profitable. LSPs must

keep the environmental, social and economic pillars of sustainability in balance, while supplying the demand.
In Europe alone, transport activity is high, and continues growing – estimates suggest that passenger transport will increase by 42% by 2050 and freight transport by 60% (European Comission 2019, Transport in the European Union: Current Trends and Issues, 1).

According to Per Hilletofth, a professor in Logistics, the logistic distribution of the future must be able to provide services and solutions in both a sustainable and cost-effective way (Hilletofth 2017).

These claims were also supported in the European commission 2011 White Paper on transportation. This paper endorses alternative ways of developing trans-European transport networks with the TEN-T project funds. This project aims to enable the private sector to achieve its objectives, which would support the possibility of a hyperloop system becoming a part of this core network in Europe. (Musk 2011, 28.)

To ensure a balanced and sustainable future, we must prepare for a transition to a substitute or find an alternative to air, ocean and road transportations, such as the hyperloop system.

These are the core concepts of this study, to evaluate the possibility of hyperloop technology as an alternative way of transportation that could be both beneficial and sustainable. The study examines both challenges and benefits within these three areas of perspective.

Figure 3. Theoretical framework.

The primary purpose of this study was to examine if it could be possible to implement a hyperloop system to improve logistic transportation without impacting negatively on sustainability. Therefore, it only covers what a hyperloop system was and what advantages and possibilities for implementation there were at the time of writing. This leads to the following main research question:

What improvements to sustainability can be achieved when combining a hyperloop system with the resources available today?

The theoretical framework in this thesis is focused on the possible effects, benefits and disadvantages of implementing hyperloop technology to sustain increasing demands, without having a negative effect on future sustainability. The study does not cover similar technologies such as high-speed rails or maglev trains, nor does it cover other parts relating to sustainability than economic, environmental and social factors. Subsequently the following sub-questions were made to find an answer to the aspect of sustainability:

Can this be a solution for logistic sustainability that would not impact negatively on either of the public sector nor its private counterpart and to do so without the expense of the environment?

Could this be a viable solution for transportation in Northern Europe?

This thesis was written using qualitative research methods. The resources for literature examination and theoretical parts were based on studies, papers and articles, many of which were published by larger institutes or organizations such as the European Commission. These scientific resources were related to hyperloop technology and sustainability and they provided a broad scope and many views on the topic. Since they included discussion on different aspects, benefits and challenges, the resources also increased the reliability of this study. All resources were scientifically related, excluding news or information that had been published anonymously or by people not associated with the field.

This study revolved around future technology and methods for transportation, making the future studies approach a natural choice. Future studies, as a method, explore future possibilities and solutions in the long term varying between 5-50 years. This method is applied by leaders in organizations as it gives a way of explaining and evaluating the big picture. (Inayatullah 2012.)

Comparative and observation research methods were used for the analysis of the materials in this study. This was because of them being appropriate when analyzing technology, future development and innovations as these methods gave a broad coverage of both thoughts, standings and views for the topic. This combination allowed for the understanding and evaluation of not only the technology itself, but also on how it was perceived by different stakeholders. In addition, questions for the empirical part were formulated with the knowledge gained from theory.

As comparative research was largely used to balance papers between each other by comparison and evaluation, the observation method helped to link the empirical and theoretical parts of the study.

The observational research method was used to define what researchers and developers were aiming for with their projects. By doing so, some patterns could be seen between different papers and studies, such as progress and objectives. This method assisted with the construction of the theoretical base which was used in the creation of questions for the empirical part. (Wildemuth 2017, 220.)

The comparative research method was used because it enables comparing of technologies in their early stages. This method gave insight to where the technology and respective organizations developing it were and what progress they had made. (Routio 2007.) With eight organizations developing and studying this technology and field in transportation, comparative research analysis was used to revise what the current overall state of the technology was.

The empirical part of this study was conducted by interviewing experts in the logistic field for advice and input regarding the challenges and data discovered in this study. One of these experts was Per Hilletofth (PhD), a professor of Operations and Supply Chain Management at the University of Gävle in Sweden. The other expert interviewed for this part of the paper is a professor within business and logistics from a university in Finland.

The information and knowledge that were gained from both literature and experts were used throughout this study and in the conclusion of the study to justify and assess the conclusion and challenges within this thesis.

The study begins with introducing the research question, objective and justification for the study, alongside the theoretical framework.
To further support the first chapter, the second chapter explains parts of sustainability and why it is important for the research questions and thesis objective.
In chapter 3, the hyperloop concept is explained and evaluated at its current state. The fourth chapter supports the previous chapters by examining innovative

solutions for overcoming challenges encountered during the earlier parts of the study.

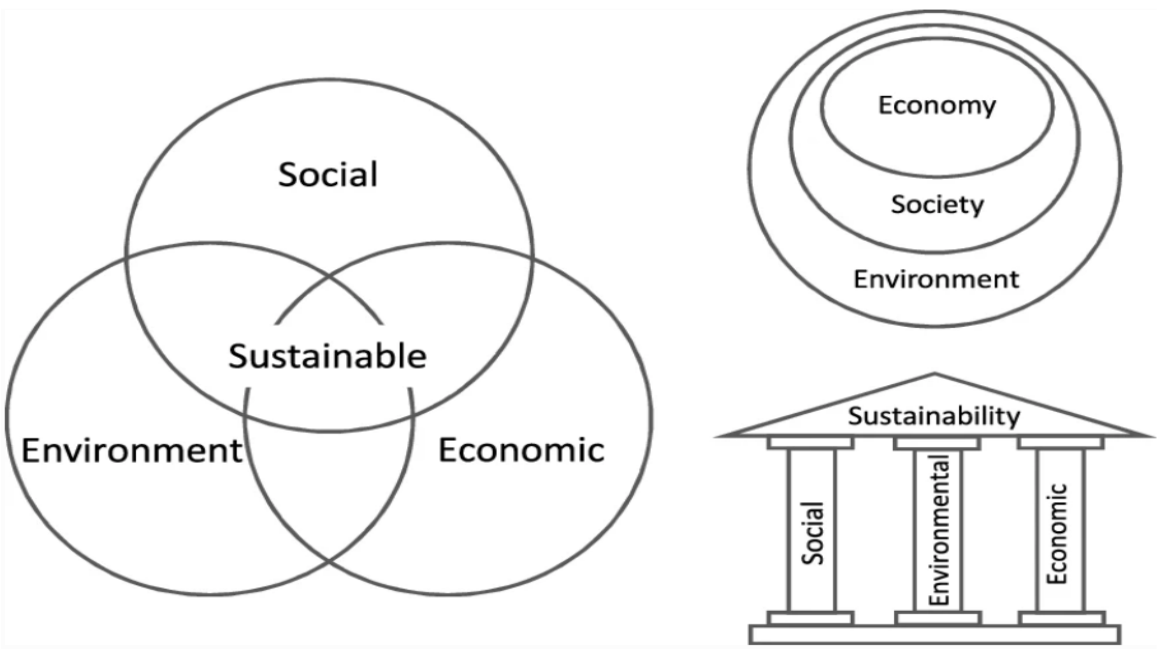
Chapter 5 describes the empirical study, followed by the last chapters 6 & 7. These chapters include the conclusion, its discussion and reliability.

3 SUSTAINABILITY

Sustainability in this thesis is consistent with the three (3) pillars of sustainability

1. Social
2. Environment
3. Economic

The most common visualization of sustainability is often referred to as three intertwining circles picturing social, environment and economic sustainability. In the middle of their connection, sustainability is depicted (figure 4).



Left, typical representation of sustainability as three intersecting circles. Right, alternative depictions: literal 'pillars' and a concentric circles approach

Figure 4. Sustainability visualized (Purvis, B. et al. 2018).

This perception of sustainability makes it possible to understand and visualize how we must take not only one area, but all three into consideration when planning for or developing new technologies and solutions. As each area is crucial for the others existence.

Typically, the economical factor is prioritized over both the environmental and social factors in general. This is however not a feasible arrangement as economics are dependent on society, while society is depending on the environment. In order to achieve sustainability, each part has to be managed on the same level. (Giddings et al. 2002, abstract.)

In 1987 the UN Future Brundtland report defined sustainability as:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

In addition, it contained two key concepts:

1. *the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given*

2. *the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.*

The definition above has been developed and extended over the next three decades into the United Nations development programme: 2030 Agenda for sustainable development. This is a set of 17 objectives (goals) to improve sustainability (figure 5) and was released in September 2015.

Figure 5. Sustainable Development Goals (SDGs) (United Nations, UN 2015).

The long objective for involved organizations is most likely profit. But alongside this, an alternative way to reduce emissions while supporting the above objectives for sustainability could be achieved.

Economic sustainability is the area where the economy and capital factors are being defined and set into policies. These should promote and maintain current and future jobs, give incentives that support sustainable innovations, impact positively on costs by developing product lifecycles to reduce waste and reduce risks for new technologies supporting sustainable solutions. (EPA 2015.)

As stated by the UN in the “Transforming our world: the 2030 Agenda for Sustainable Development”, poverty is recognized as the most significant global challenge and an indispensable requirement for sustainable development (UN 2015, 3).

In this study, economic sustainability examines how the system could be profitable for the owners without affecting negatively on third parties, such as businesses or stakeholders.

Because of the project being a large investment, requiring each government of respective countries to use much capital, costs for the project must be optimized to prevent negative economic outcomes.

An example of keeping costs as low as possible, present infrastructure could be utilized as base for the hyperloop system. This could also allow for greater public support for the project as the need for public funds would be lower.

Environmental sustainability is referred to as how changes to the nature can be made without impacting negatively on factors such as surrounding ecosystems, landscapes or decarbonisation. These factors can be assessed with the Ecological footprint tool which provides perspective on sustainability. This tool is based on that harvesting of natural resources which are renewable should not exceed their regeneration rate. (Syrovátka 2020).

As mentioned in the Brundtland report, sustainable development must take upon the responsibility of ensuring the preservation of natural life-supporting systems on Earth such as the atmosphere, waters, soil and living beings. In addition, a responsible management of natural and limited resources must be maintained.

The system studied in this thesis could support environmental sustainability by using alternative energy sources which could all be emission free, such as solar or wind power.
In addition, hyperloop systems could utilize present infrastructure for supporting the system’s base pillars themselves. Straight highways and railways would be logical places for building the system, to minimize costs.

Because of the pillars being estimated to take roughly the same space as a telephone pole with the capsule being inside a closed tube, the system itself will be more environmentally sustainable. This reduces both noise pollution and changes to the landscape. (Musk 2013, 24-25.)

Consequently, the transition from the movement of goods from trucks to hyperloop, a significant amount of emissions, noise and particles could be prevented. High populated areas and city lanes prone to traffic jams could also see a decrease in occurrences or the duration of these. (Nikitas et al. 2017, 10.)

Social sustainability is the least defined section of sustainability since the other sections are often more discussed. However, social sustainability is often described as how implementation or decisions will affect society.

Some of the major aspects to this are health, ethics, equality, politics and overall wellbeing of the society and people. When governments set social policies, they will have a direct impact on both the economic and environmental factors in sustainability, as they affect the welfare of communities and individuals.
Lately there has been a shift towards eco-social policies and care economy, where sustainability as a whole is being adapted. (United Nations 2015, 1-3.)

Eco-social policies incorporate environmental concerns to ensure and support the development of environmentally sustainable resource use or management. For example, this can be the development or shift into energy efficient public transport or the rehabilitation of ecologically degraded areas.
Care economy is one of the foundations for a sustainable society and economy. It ensures the wellbeing of the labor force by including the caring for children, elderly and sick. This improves gender equality and the economy by enabling women to work while creating more jobs and alleviates the social burden of reproduction. (United Nations 2015, 1-3.)

As a part of this study, social sustainability could be endorsed by the mitigation of unemployment and the encouragement of people to populate scarce areas. This could be achieved by locating main hubs and larger transition points remotely, while smaller hubs would be in the city area. By doing so, road, railroad and maritime logistic operators could be used for last mile and domestic deliveries, instead of operating long distances. (Nikitas et al. 2017, 10.)

4 WHERE HYPERLOOP IS TODAY

The eight organizations involved in the development of hyperloop technology have all had their Technological Readiness Level (TRL) assessed. Technology Readiness Level of 3 is described as: Experimental proof of concept. While a level of 4 is: Technology validated in a lab. (HORIZON 2020. 2017, 29.)

In 2018, almost everyone received a TRL level of 2-3, on a scale 1-9, with good opportunities to reach TRL 4. (Magnusson & Widegren 2018, 101-106.)
Some have achieved this later stage. For instance, Hyperloop TT completed their test track in Toulouse, France in 2019, reaching TRL 4 by testing their Quintero capsule in this 320m long system (figure 6).

Figure 6. HyperloopTT test track (HyperloopTT 2019).

Human trials are scheduled for 2020 which would be a step closer to TRL 5, technology validated in a relevant environment (industrially relevant environment in the case of key enabling technologies). (PRNewswire, 2019.)

In this study, a system would be connecting Helsinki and Copenhagen via Stockholm and Gothenburg (figure 7), with a total length of almost 1023km (1022.64 km (635.44 miles).

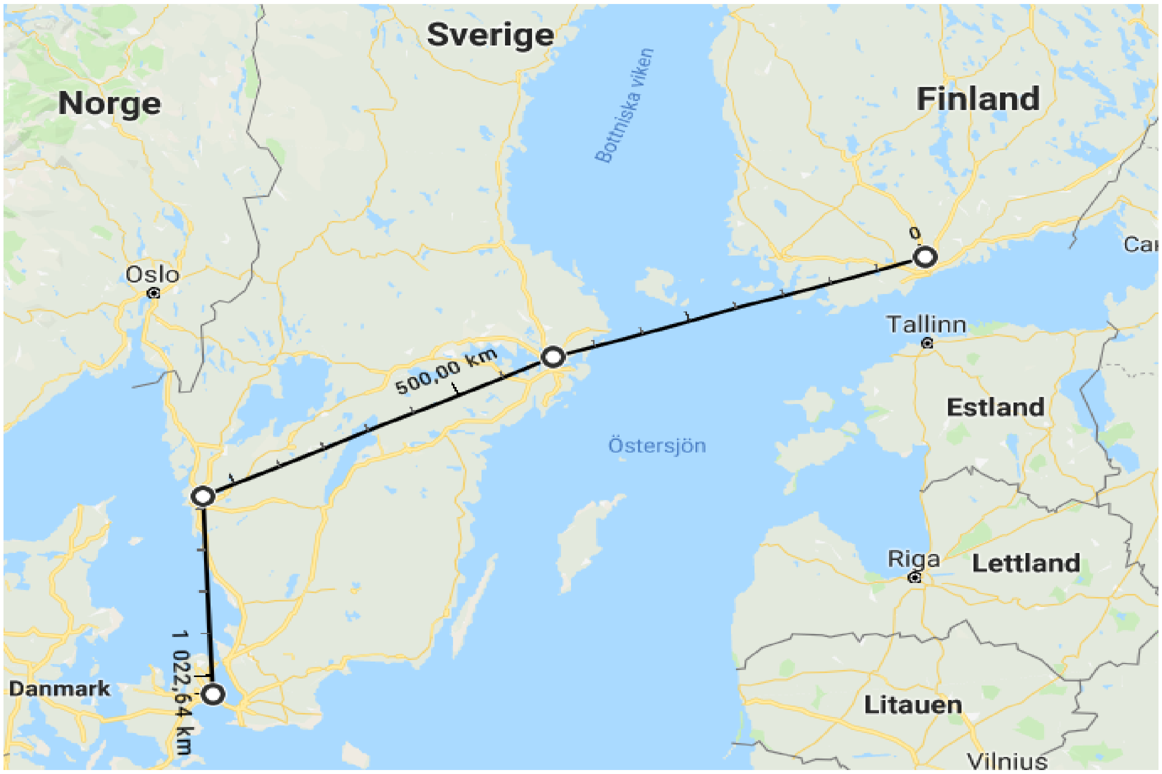


Figure 7. Study hyperloop system.

4.1 Hyperloop system cost

For the calculation of the hyperloop system cost for the system track in this study, with a length of 1,023km, other cost estimates from different organizations and projects were used as a comparison. Average cost was calculated to be €19.5 billion, with the estimates from the following examples.

Musk's estimate in his white paper (2013) was $6 billion for a system length of about 350 miles which is close to 563 km. This gives the system in this study a price of approximately €10.13 billion.

According to the KPMG feasibility study (2016) for a Hyperloop One passage between Helsinki and Stockholm, cost per km was estimated to €26 million. In addition, Hyperloop One estimates that their 150 km long track between Dubai and Abu Dhabi would cost up to $4.8 billion which is €4.46 billion (Konrad 2016). This gives a cost estimate for the system visualized in Figure 7 to be approximately €26.6 billion and €30.41 billion, respectively.

The 60 km HyperloopTT project in Tongren, China, is estimated to cost ¥10 billion, equal to almost €6.3 million (Huang 2018). With this estimate, a 1023 km system would cost approximately €10.72 billion.

By adding these systems together and calculating an average, the before described system (figure 7) would be close to €19.5 billion.

4.2 Benefits

Many of the improvements in transportation that comes with the hyperloop system are closely linked to sustainability and transportation times.
This could also reduce the increasing air pollution emissions released by conventional road transportations. From 2013-2016 emissions increased in this field with 5%, this shows that current systems might not be sustainable. (Transport in the European Union: Current Trends and Issues, 14.)

As aviation is projected to have an average increase of 2.7% annually until 2040 (European aviation in 2040: Challenges of growth, 32). The emissions derived from increased aviation could be mitigated by hyperloop technology. Short distance flights between capitals in Northern Europe would no longer be required, as such a considerable amount of GHG -emissions could be prevented.

In 2019, total passengers (arriving and departing) to Swedish airports Arlanda (Stockholm) and Landvetter (Gothenburg) amounted to 5 090,547. This number includes domestic flights between these two cities. (Swedavia 2019.) As these destinations are half of the major hubs for the system in this thesis, we can use this amount as reference for annual passenger estimates. With a per way ticket price of €20, a price similar to that of Musk's (2013) ticket price, annual revenue could be €101.8 million.

Werner et. al concluded with their study in 2016 that a hypothetical hyperloop system with a length of 300km in Northern Germany was likely to give an annual shared value revenue of €660–900 millions. This value was estimated by calculating 8 factors considering transportation to pollutions and accidents.

For example, up to €401 million could be generated by the shear reduction of travel time in cargo transportation alone. Adding the replaced trucks for the same route, road capacity could increase with at least 150 cars per hour, while reducing the chance for possible traffic deaths by 80–144, yearly. (Werner et.al 2016.)

In July 2016, Hyperloop One, FS Links and KPMG published pre-feasibility study for connecting Helsinki and Stockholm with a hyperloop system. The proposed link would be approximately 500km and reduce travel time to 28 minutes, considerably shorter than today. It was estimated that such a system would add almost 25M hours in value of time annually due to time saved per travel. (KPMG 2016, 2-9.)

This solution could be extended to connect Stockholm with Copenhagen, a distance of approximately 630 km, reducing the travel time from Helsinki to Copenhagen, to a bit over an hour.

Denmark is aiming to be independent of fossil fuels by 2050, to reach this objective they seek to market driven ways of funding and developing infrastructure and technology, without straining the public finance.

Today Danish roads around larger cities are prone to traffic jams, and it has been projected that by 2028 the amount of time stuck in a congestion will rise with 150%, while the overall quality of infrastructure in Denmark has declined. (Transport in the EU 2019, 40-44.)

An electrically powered hyperloop system could be a solution for avoiding the increased time spent in traffic congestions. Using hyperloop instead of trucks, both the wear on infrastructure and time spent in traffic, could be reduced. Less usage of conventional road traffic reduces emissions generally, which would help Denmark reaching its emission objective.

Finland has today a very extensive road and railway infrastructure, however they have an annual shortfall in maintenance, around €2.5 billion. In addition to this, the railway track gauge is the same as of Russia with 1 524 mm. This makes it impossible for trains to cross the border to Sweden, which has only 891 mm. (Transport in the EU 2019, 148-152.)

Subsequently, the fastest way to travel Helsinki – Stockholm today is by plane or ferry, this takes around 1 and 16 hours respectively.

These challenges in Finland could be eased by using hyperloop as a substitute for cross-border transportation as it would make it possible to shorten travel times considerably, even allowing inhabitants to commute between Helsinki and Stockholm daily.

Sweden has set the objective to be emission free by 2045, and negative after that (Swedish climate policy council 2019, 11).

In Sweden, 90% of the goods are being transported by road domestically and over long distances. The railway network is also largely powered by diesel trains, instead of being electrically powered. As in all countries, traffic congestions around larger cities are common. (Transport in the EU 2019, 153-157.)

As mentioned earlier, Sweden has a narrow railway gauge which leads to problems when crossing borders, creating longer transit times to Finland alongside increased costs for shifting carts or multimodal transportation.

By implementing hyperloop technology Sweden could reduce long domestic transports while reducing traffic congestion. Reducing road traffic would also decrease both traffic fatalities and emissions, which Sweden also has an objective to zero out.

Because of Sweden being in the center of Northern Europe while having long distances between major cities, there is a considerable number of regular shorter distance flights. From Arlanda to neighboring capitals and domestic cities such as Malmö or Gothenburg, airtime travel ranges from 1-2 hours.

4.3 Challenges

There are many challenges linked to hyperloop technology and innovations overall, typical areas are: safety, technology, profitability, scalability etc. Some of the larger issues and challenges identified and discussed so far are described here.

Because of the high speed, curves and bends in the system will subdue the passengers to tremendous force, upwards to 1.5g. In order to ensure passenger comfortability and safety, this will have to be solved. (Ross 2016, 51-54.)

Another main challenge that was identified is that the topology and infrastructural differences between the USA and Europe. For instance, roads and highways in the USA are wider and straighter than European counterparts, the same as the topology itself. In Europe, more tunneling must be made which is increasing costs while making safety harder to achieve. (SAC 2016, 3.)

Furthermore, practical challenging examples are standardization and the development of high-speed switches. Both need to be developed to ensure a smooth implementation and the possibility to create an innovative, smart and optimized network.

However, these are natural elements in projects of this magnitude because of the time it takes for innovations to reach the same maturity level of that which an already implemented innovation has (Doppelbauer 2018, 9).

5 OPTIONS FOR INFRASTUCTURE

This following part of the study reflects on possible solutions and alternatives for enabling the hyperloop technology's possibility. Because of the future studies nature and this paper consisting of new technologies under development, following alternatives are theoretical and their success as a solution yet to be confirmed and proven.

5.1 Utilizing today's infrastructure

Not only because of railways constant need for electricity or them being built in a straighter and more levelled line than roads, they are also built mostly separated from populated areas. These are all favourable qualities for a hyperloop system, a symbiotic relationship could be achieved with this, as major changes to city infrastructure could be avoided and power supplying infrastructures already existing.

Below (figure 8) is Sweden's railway network pictured with the green line being the track for the hyperloop system (figure 7). As seen in the below picture, a considerable part of the green line interacts with already existing railways.

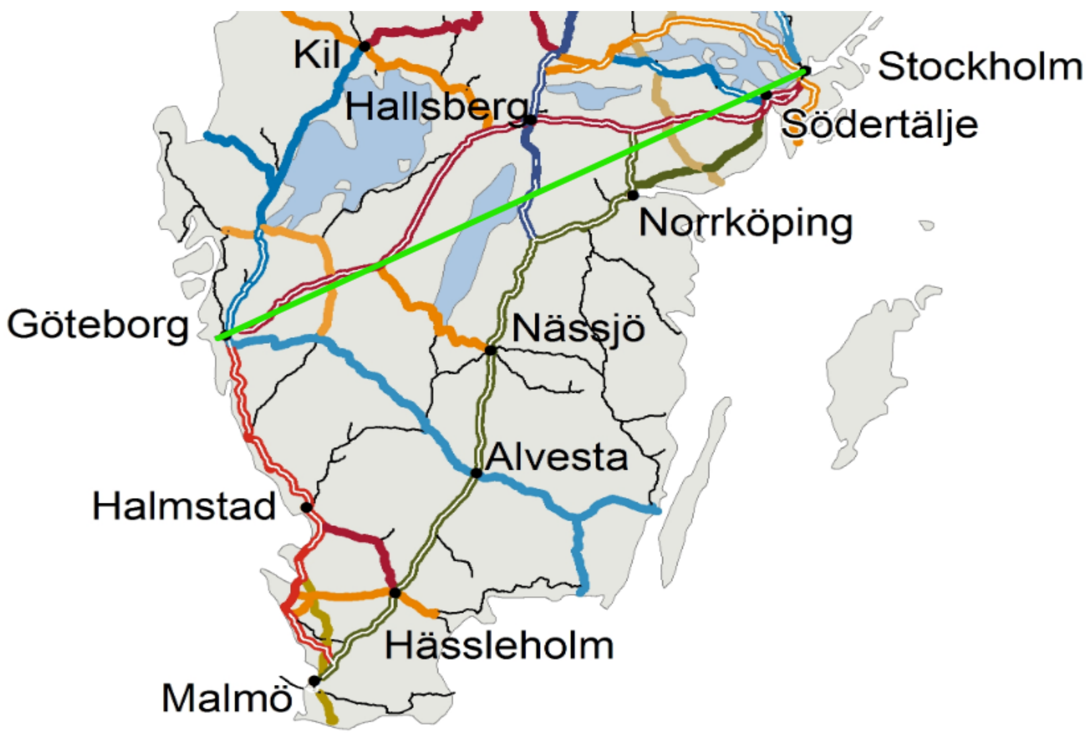


Figure 8. Sweden's railway network (Trafikverket 2019).

In Northern Europe, roads have been extensively built to enable both people and goods to be transported over long distances, by the development of the Ten-T network. They connect cities and people, domestically, also crossing between neighboring countries.

Motor traffic ways would be suitable supportive infrastructure to Hyperloop due to them being both straighter, newer and more developed than common national roads.

Sweden’s highways and Ten-T network (figure 9) is pictured alongside the hyperloop track (figure 7).

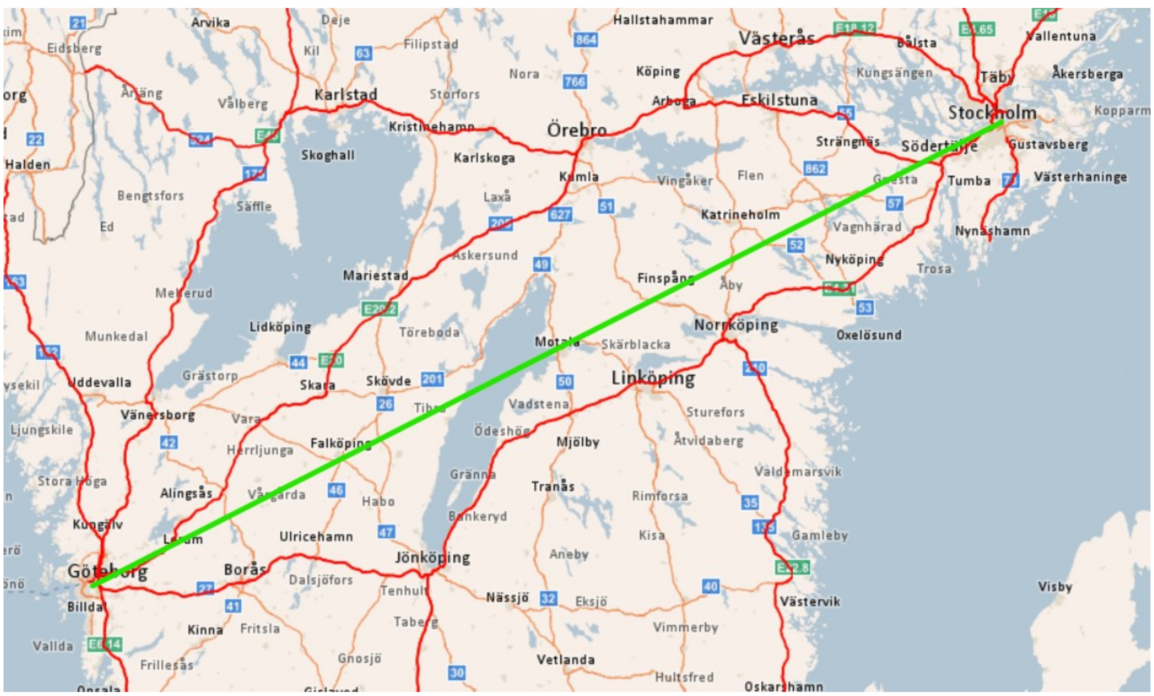


Figure 9. Sweden’s Ten-T network (Trafikverket. s.a.).

5.2 Submergible alternative

In Norway, a floating and submergible tunnel solution is being researched for crossing the Bjørnafjord and other fjord crossings with The E39 Coastal Highway Route, a project which spans 1100km from Kristiansand in the south, to Trondheim up north (Statens vegvesen 2020).

Figure 10. The E39 Coastal Highway Route (Statens vegvesen 2020).

The tubes, one for each direction of traffic, will be attached to floating pontoons spaced about 244m apart.

Figure 11. The Submerged Floating Tube Bridge (Statens vegvesen 2018).

The fjord has a depth of more than 1 200m, making it too deep for engineers to tunnel beneath it. Instead, the floating tunnel will be suspended about 30m beneath the surface of the water. This will enable ships to easily pass over it, while there will be more than enough room beneath for the passage of submarines.

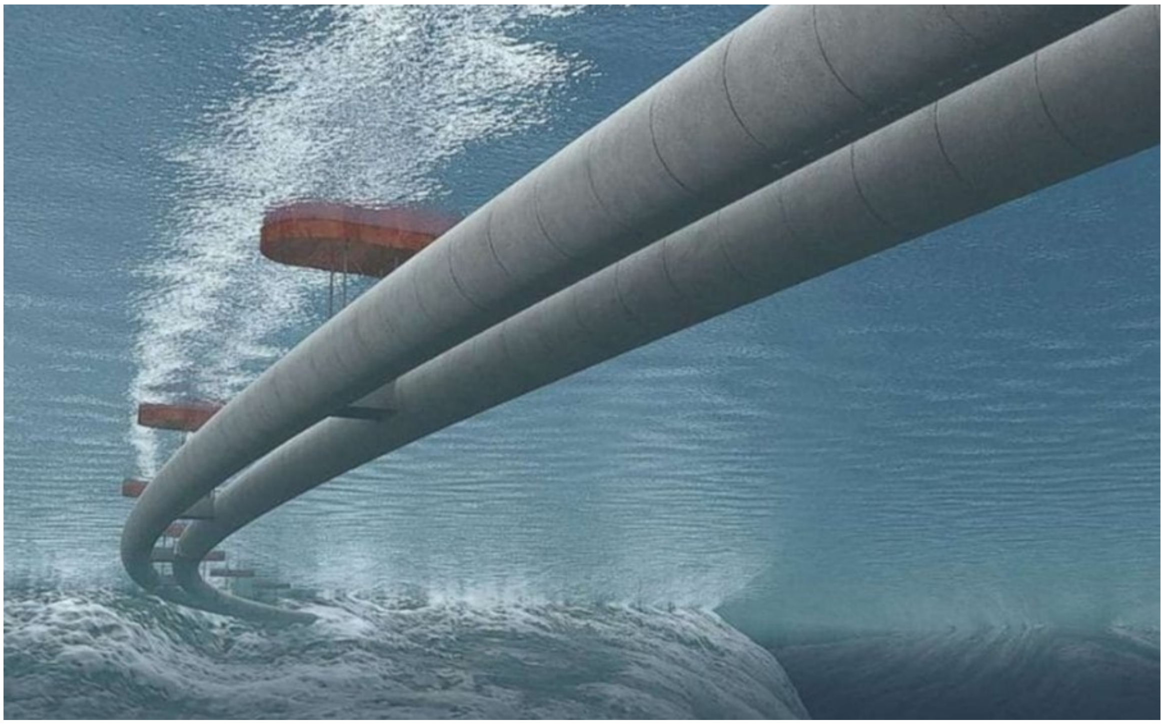


Figure 12. The Submerged Floating Tube Bridge (Statens vegvesen 2018).

This kind of innovation could be possible to use for crossing the Baltic Sea, these tunnels could also serve as a base for hydrokinetic energy sources. This would be decreasing the load on the power grid while producing green energy, as underwater power sources could be attached to the structures.

6 POWER SOURCES

The Hyperloop system mentioned in Hyperloop Alpha paper (2013) has been calculated as self-sufficient. However, the biome and weather in Northern Europe is almost the opposite, in comparison to that of California which the paper mentions. This must be taken into consideration when planning for the system is in the making.

Musk calculated in his white paper 2013 that the propulsion needed for his concept hyperloop system passenger capsules to require 21MW, passenger and vehicle capsules would require 49MW. The transportation tube itself provides 6.6m wide surface for panel installation and capsule batteries for energy storage. These batteries would provide for the average consumption of 6MW while the peaks of 55MW would be drawn from the power grid. (Musk 2013, 27-39.)

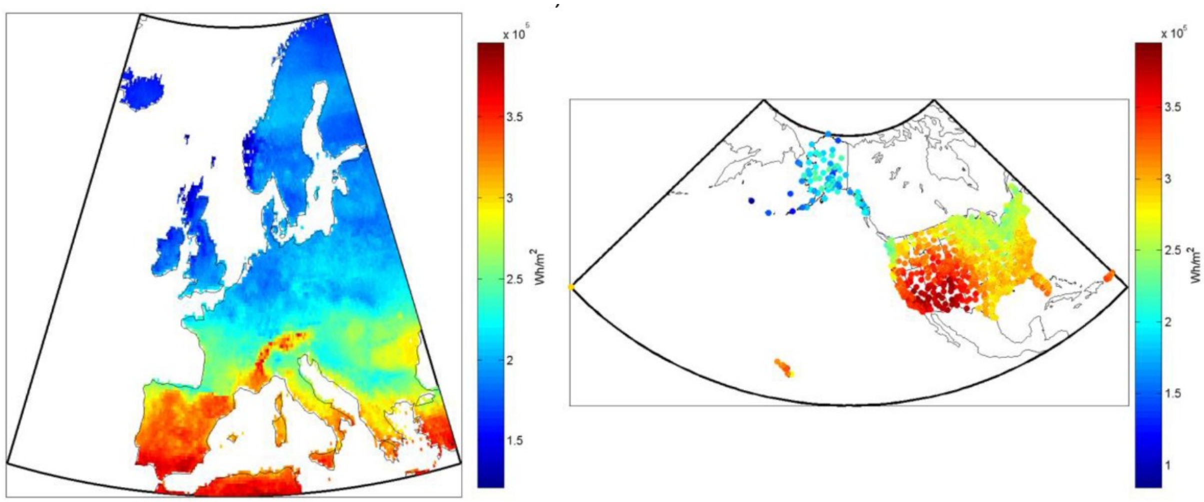
As alternative ways of supplying energy could be by utilizing both wind, solar and oceanic energy sources, implementing them at the best demographical area for each energy source respectively. Concept pictures of the energy sources described in this chapter can be found in Appendix I.

As the system visualized in this thesis (figure 7), roughly 500 kilometers are located offshore, these parts could provide for a solid supply of greener oceanic energy.

Solar energy is energy harnessed from solar radiation. Its irradiance is affected by factors such as cloudiness, aerosols, moisture and of course the number of sunny days. This results in a variance between areas, or countries, of how much irradiation can be collected, which in turn affects energy output for the solar panels.

As the solar irradiation averages approximately 2.25 x 10^6(Wh/m^2) in Denmark, Finland and Sweden, it averages over 3.5 x 10^6(Wh/m^2) in California, pictured in (figure 13). Musk expected the solar cells to produce an average of 120W/m^2, as the irradiance in northern countries is about 64.29% as that of California, the possible output could reach roughly 77W/m^2.

However, ice, snow and water reflect solar radiation and thus increases panel output, in addition cold temperatures reduce energy leakage in silica panels, this panel type accounts for roughly 80% of the solar panel market. (Norwood, Z., Nyholm, E., Otanicar, T., Johnsson, F. 2014, 3.)



b)

Figure 13. Global irradiance in Europe and the US annually (Norwood, Z., et al. 2014).

As the system pictured earlier (figure 7) has approximately 473km of its length on land while 550km are submerged, this amounts up to an area of 3 121 800m² (referring to a system width of 6.6m as described by Musk 2013) for which could be covered with solar panels.
An area of this size could amount for up to 240MWh of solar energy alone. If the whole length of the system could be constructed above ground, solar energy output could be as much as 520MWh.

Combined with oceanic and wind, the proposed system would need little to no energy from other sources of energy.

Offshore energy was in the following part of the study based on the information from the article Renewable Energy on the Outer Continental Shelf by the Bureau of Ocean Energy Management (BOEM).

An offshore wind energy turbine works by utilizing wind to rotate a propeller blade which in turn rotates a turbine, generating electricity. This innovation is resembling redular wind turbines, both technically and cosmetically. Because of the winds tending to be a lot stronger offshore than onshore, they generate more power.

Similarly to the wind turbine, there is also Ocean current energy. This is a hydrokinetic version which utilizes underwater currents for propelling the blades which turn the turbine.

A very innovative solution could be the Ocean wave energy, which is also hydrokinetic. This generator is equipped with large screens instead of blades. These screens are pushed back and forth by the surface energy generated by the waves. This technology is however dependent on waves. Because of this, they must be placed in shallower water or closer to the surface than turbines equipped with blades.

7 EMPIRICAL RESEARCH

The interviews for the empirical part of this paper were made through March to May 2020. Because of the Covid-19 peak that was present at the time contributed to prolonged responses while fully removing the possibility to interview in person.

Because of the empirical part being limited to only email correspondence and the ruling Covid-19 situation affecting work hours, I did receive a less than anticipated and wished for amount of material for the paper.
The sole opportunity of opening questions and answers was removed, resulting in the empirical interviews becoming more of a statement, than the informational discussion that would have been needed to support the study on a broader base.

As the study formed and evolved into its final forms, many alternatives for the empirical parts were removed due to their irrelevance to the content and areas of expertise.
This led into four different options, whereas the following two could be reached for comment and agreed to participate in the study.

After Per had been interviewed via email, he referred me to one of he’s colleagues for more profound views and knowledge of hyperloop technology and global supply chains, this person wished his answers to be anonymously included within this study.

This professor has been involved in researching fields such as high-speed rail systems, global supply chains and logistics.

7.1 Per Hilletofth (PhD)

Mr. Hilletofth was working as a professor of Operations and Supply Chain Management at the University of Gävle in Sweden at the time of the study.

Already in the early stages of this study, Mr. Hilletofth was regarded as a prominent source for the empirical part.

As mentioned in his presentation in Jönköping university:
"His research is in the area of operations and supply chain management with a particular focus on strategy, sourcing, demand and supply planning, information systems, and social responsibility. He has published more than 100 refereed papers in scientific journals, books, and conferences.
He has been contributing to numerous researches focusing on supply chain management, design, strategies and related technologies."

These following questions were sent to Per Hilletofth (PhD), his original answer in Swedish can be found in Appendix III.a.

1. What do you believe we must change or develop further within transportation/logistics to achieve a more sustainable future?

2. What must we do or change to improve transportation/logistics overall?

3. What do you see as the greatest challenges for transportation/logistics?

Translation of Mr. Hilletofth's answer:

"During the last decades, the focus has been on building large factories with the aim to produce and deliver large volumes on to a global market. Production has been moved out to low-cost countries which have created more complex and global supply chains. In the future, we must develop more local/regional supply chains in order for us to reach set environmental objectives. We need to develop transportation and logistical solutions which support a more local production and supply. Corona (Covid-19) has pointed out this need, in particular when global production comes to a halt due to the closing of China."

7.2 Contributing professor

This professor was referred to me by Mr. Hilletofth and wished for his answers to be included anonymously.

With numerous relevant contributions to the academic society, this person also contributed with very useful and viable information and insights for the empirical part of this study.

Some excerpts from his Curriculum vitae:

The professor is familiar with areas concerning industrial management, supply chain management, system dynamics and transportation systems.

Additionally, this person has published over 300 professional publications, including books, conference proceedings, research reports, international journal manuscripts, working papers and international conference articles.

The set of questions sent consisted of seven main questions and six sub-questions (Appendix III.b).

8 CONCLUSION

The objective of this study was to achieve an overview and understanding of hyperloop as a new transportation technology and what benefits and challenges it was facing at the time of writing.

Additionally, this paper studied the viability of a theoretical system between Finland, Sweden and Denmark.

As global organizations and governments are aiming for net-zero emissions and increased overall sustainability, this study examined how some of the challenges within these set objectives could be mitigated.

This study began in March 2019 and followed both set objectives and developments made up and until Covid-19 and well into 2020 post Covid-19, many variables have had unforeseen changes which have affected both this study and the progress for hyperloop technology.

Because of the uncertainties and strain on society from Covid-19, unemployment and restrictions within transportation and directions for social distancing have increased. This contributed to unforeseen and unprecedented effects on transportation and society as a whole.

Due to these factors, it was not possible to reach a decisive conclusion on whether hyperloop can be achievable or even viable in the near future, post Covid-19.

Clearly this has impacted negatively on both the private and public sectors, which would be further worsened if hyperloop technology would be implemented today. It is obvious to say that implementations of new technologies and infrastructure have been postponed, delaying their initial development strategies.

The set of research questions have been divided into sub-chapters where their respective answer and the leading conclusion is explained.

What improvements to sustainability can be achieved when combining a hyperloop system with the resources available today?

Theoretically they are many. Emissions could, for instance, be drastically reduced from short flight aviation and maritime pollutions due to the Helsinki-Stockholm link. In addition, traffic congestions around cities could also be mitigated, to some extent.

With shortened travel time between cities, workforce could be extended and opened for cross-border commuters, promoting development in businesses and creating new opportunities for communities.

On the other hand, Nordic countries have a very well developed transportation network already in place for all sectors (air, road, rail and maritime traffic), a new technology and its infrastructure would divert resources from these critical infrastructures, even more post Covid-19 and relief packages.

Innovative and currently available solutions for building green energy networks on top, or below, the pictured system in this paper could provide for cleaner energy in the region.

Because of hyperloop still being in its early-mid development stage, many of the proposed calculations and utilizations mentioned by experts and studies, have not in fact, yet been tested or proven and therefore exist solely in theory.

Can this be a solution for logistic sustainability that would not impact negatively on either the public sector nor its private counterpart and to do so without the expense of the environment?

The effects of reduced air and road traffic has been seen all over the world. In areas where smog and pollution were severely harming both society and the environment, shutdowns have shown drastically improved conditions. Hyperloop systems could improve these conditions to some extent which could alleviate traffic and pollution related harm on all three sectors.

It was shown in the paper Shared Value Potential of Transporting Cargo via Hyperloop (Werner, M., Eissing, K., Langton, S. 2016.) that the strain on the public sector could be reduced due to improved health and reduced traffic related accidents, which are correlating with reduced road traffic.

By utilizing the Ten-T network as much as possible for the base infrastructure, while expanding green energy networks alongside, a hyperloop system could reduce environmental harm, thus being a sustainable logistic solution.

Likewise, the private sector would profit from reduced lead times and increased supply chain security, which would allow for better optimizations.

Since the Covid-19 outbreak in 2019, countries and businesses are even more strained with uncertain futures and governments weighed down by heavy support packages to many areas, such as aviation which saw a drop in April 2020 by 90-99%.

The Northern European public transportation structure relies on a balance between privately owned systems supported by governmental subsidies. This usually prolongs larger and costlier projects since they will require a majority support within politics and ultimately, from the public.
Hyperloop could inevitably have a negative effect on both the private and public sector, even more now when countries must rebuild and reassess their economic situations which were severely disrupted by the Covid-19 outbreak.

In addition, the hyperloop technology and its supporting infrastructure could also have unforeseen impacts on areas such as environmental safety and wildlife. This ultimately leads us to the conclusion that it is yet too early to tell.

Could this be a viable solution for transportation in Northern Europe?

If hyperloop could be a viable solution for transportation in Northern Europe the conclusion is divided.

There are feasibility studies made in America, Asia and Europe which are positive towards hyperloop as a solution to overcome many of today's challenges with both GHG emissions, profits and travelling.

On the other hand, some experts imply that this technology is just an expensive "fancy new tech" that would face great financial issues due to the low and scarcely populated areas, making the gap between disadvantages and benefits too huge.

For example, the transportation systems in Northern Europe are relying heavily on governmental subsidies and because of hyperloop technology depending on new infrastructure, the economic benefits can be hard to realize.

In addition, it was discovered that all developing organizations had the same TLR level and were all aiming for a commercial system for transportation usage. This implies that there is still a very long way to go before we can see a functional commercial system.

The time still needed in development increases the risk of change in public will and politics might cause further delays in development. In the worst change scenario, the focus moves onto something else, that might already be existing such as Maglev or aviation.

Furtherly, the utopian examples that are theoretically possible are being harshly questioned by experts within both logistics and business, pointing out that they might be too ambiguous to achieve in real life.

9 DISCUSSION AND RELIABILITY

The aim of this thesis was to create a study based on facts regarding the technology of hyperloop and to find out what possibility for implementing it in Northern Europe.

Because of the new and experimental nature of Hyperloop, there were no previous studies for this area of technology available at Theseus. This was of both a positive and motivating nature, but it also increased the challenges and required research needed in order to reach conclusions.

A clear challenge was to find and reach experts for the empirical part of the study. For example, the only available hyperloop study available was the KPMG Pre-feasibility study Stockholm – Helsinki using Hyperloop One technology (2016).
Participants from this study could not be reached as their contact details were outdated. These participants would have had tremendous amounts of knowledge for supporting this study.
This however points out the lack of interest and even possibly the awareness of hyperloop and most likely also other alternative transportation technologies in Northern Europe.

In addition, the empirical part also encountered challenges because of Covid-19 limiting the possibility to interview experts, as their time and availability were restricted due to changed routines and working hours.
A direct negative outcome of this was that questions had to be sent by email and could not be benefited the same way as a live interview, questions could also only be sent once, without adequate follow-up.

The research questions that were set at the beginning of the study were challenging to cover in a matter that would be reflective and accurate.
Straight answers for these questions were not found at the time due to the stage of the technology and its surrounding hype creating strong reflections from both critics and supporters.
However, future studies could be based on facts described in this thesis and further examine used resources, comparing them with new research.

Because of this being a bachelor's thesis, there are many areas yet to be examined and developed. To name a few prominent areas needing further studies, I have made this list:

Can de-globalization promote de-carbonization, could hyperloop support this goal?
Could short distance aviation be replaced with another technology such as hyperloop?
The derived effects from alternative transportation technologies on transportation safety.
Green energy solutions for supporting alternative transportation technologies in Northern Europe and their symbiosis.

Reliability is ascertained because I had no connections to any of the sources referred to in this study, nor did I gain any economical or other benefits from this study.
Because of the study examining possible future technology and its reliability, an impartial and objective view was kept.

However, the technology is globally trending and very new which makes people, organizations and institutes more prone to support it. This should to some extent, be taken into consideration when studying this field of technology.

For instance, the European Commission/Union has a direct interest in supporting sustainable technology which can at the same time enhance and support scholars and universities within the union. This gives the EU a technological advantage and possible economic gain over other institutions or organizations.

Experts interviewed in the empirical part of the study, answered sent questions with personal views, not necessarily on behalf of their affiliated organizations.

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List of Figures

Appendix I

Oceanic power sources, illustrated by the Bureau of Ocean Energy Management

Oceanic wind turbine

Current energy

Wave energy

Appendix II

G. Technology readiness levels (TRL)

Where a topic description refers to a TRL, the following definitions apply, unless otherwise specified:

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Appendix III.a

Questions and answers from the empirical research (1/2)

The following questions were sent to Per Hilletofth (PhD), a professor of Operations and Supply Chain Management at the University of Gävle in Sweden.

1. What do you believe we must change or develop further within transportation/logistics to achieve a more sustainable future?
2. What must we do or change to improve transportation/logistics overall?
3. What do you see as the greatest challenges for transportation/logistics?

<u>Translation of Per's answer:</u>

"During the last decades, focus has been on building large factories with the aim to produce and deliver large volumes on to a global market. Production has been moved out to low-cost countries which has created more complex and global supply chains. In the future we must develop more local/regional supply chains in order for us to reach set environmental objectives. We need to develop transportation and logistical solutions which support a more local production and supply. Corona (Covid-19) has pointed out this need, in particular when global production comes to a halt due to the closing of China."

<u>Original answer:</u>

"Under senaste årtionden har fokus varit att bygga stora fokuserade fabriker som ska leverera ut höga volymer på en global marknad. Produktion ha flyttas ut till lågkostnadsländer och det har skapat komplexa och globala försörjningskedjor. I framtiden måste vi utveckla mer lokala/regionala försörjningssystem för att nå hållbarhetsmålen. Vi behöver utveckla transport/logistiklösningar som supportar en mer lokal produktion/försörjning. Corona har uppmärksammat detta behov särskilt, när hela världens produktion stannar upp när Kina stänger igen."

Appendix III.b

The following questions were sent to a Professor of Engineering Science.

The person allowed for his/her answers to be anonymously included within this paper.

Questions from the empirical research (2/2)

1. What improvements to sustainability could be achieved when combining a hyperloop system with the resources available today?

2. Can this be a solution for logistic sustainability that would not impact negatively on either of the public sector nor its private counterpart, without the expense of the environment?

3. Could this be a viable solution for transportation in Northern Europe?

4. View on hyperloop technology
   - Possible solutions to challenges within energy, safety, track switches, crossing waters/tunneling
   - Funding for the system

Views on the future developments in transportation & sustainability

5. How will transportation develop?
   - How must it change?

6. How will sustainability be developed?
   - What must be done?
   - What can be done?

7. Challenges today and in the future of transportation
   - What do you see as greater challenges for future transportation?