Modal shift from Air to Rail

Towards a climate neutral transport sector in the EU
A backcasting analysis

MASTER THESIS INDUSTRIAL ECOLOGY

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Summary

In this research a backcasting analysis was conducted to address sustainability challenges in group travel within the European Union (EU). The study aimed to achieve climate-neutral group travel by shifting from air to rail, considering the EU's goal of becoming climate-neutral by 2050. The analysis revealed two important findings: the difficulties and drawbacks of making the train the main mode of transportation in Europe and the need to discourage air travel before improving train services in order for the train to become the main mode of transportation.

A literature gap was identified from a literature review, which showed that no studies were performed that considered pathways towards EU wide train passenger transportation to become the main mode of transportation in 2050. From this research gap the research question was formulated: *What implementation pathways are foreseeable to replace air passenger transport with high-speed rail within Europe?*

To answer this research question, a backcasting analysis was performed. In this methodology a future vision is stated from which will be worked backwards to the present and pathways can be formulated on how to reach this future vision. The future vision chosen in this research was based on already existing European goals: *In 2050 the train will be the main mode of transportation for group traveling within the European Union and is a climate neutral way of transportation.*

To gather data for the backcasting analysis, and more specifically for the formulation of the pathways towards the future vision, semi-structured interviews were conducted with experts on the topics of transportation, trains, transportation policies, and behavioural change. From these interviews, results were collected, and the pathways were formulated.

Firstly, the analysis indicated that making trains the primary mode of transportation in Europe poses significant challenges. While trains are more environmentally friendly than airplanes in terms of greenhouse gas emissions, the transition requires substantial investments in infrastructure. The construction of new rail lines, for instance, involves significant costs and may contribute to greenhouse gas emissions. Thus, the vision of making trains the dominant mode of transportation should be approached cautiously, considering the economic and environmental implications.

Secondly, the analysis emphasized the importance of discouraging air travel before focusing on improving train services. In order to make trains the preferred mode of transportation, it is crucial to reduce the demand for air travel. This can be achieved by implementing measures to discourage air travel, such as increasing the prices of plane tickets. By raising the cost of air travel, travellers will be incentivized to opt for more sustainable alternatives like trains. This approach ensures a more effective shift towards sustainable group travel by reducing reliance on air travel and promoting the use of environmentally friendly modes of transportation.

To address these findings and achieve climate-neutral group travel, the backcasting analysis proposes several intervention points. Firstly, it is essential to implement policies and regulations that discourage air travel and incentivize sustainable alternatives. Governments can introduce measures such as taxes on aviation fuel, or restriction of the number of flights allowed, which would make air travel more expensive and encourage travellers to choose greener options. Simultaneously, investment in research and development for climate-neutral aviation technologies is crucial to enable sustainable air travel in the future.

Additionally, infrastructure investments for trains should be carefully planned to balance the costs and environmental impacts. Prioritizing improvements to existing rail systems, enhancing rail timetables, and implementing advanced traffic safety systems, like the ERTMS, can significantly enhance the attractiveness of train travel. These improvements should be implemented before considering the construction of new rail lines.

This research has contributed as a policy and decision-making support by formulating a pathway containing policies to work towards a more climate neutral transport system in Europe. The focus is on the train, but the recommendation can be used as a basis for decision-making for other transport related sustainability issues as well. Furthermore, using input from several experts for the formulation of the pathways is a methodological contribution for backcasting. The input from experts with different areas of expertise can close the implementation gap for academic backcasting studies and real world transport practices.

In conclusion, the backcasting analysis highlights the challenges and considerations associated with making trains the main mode of transportation in Europe. It underscores the need to discourage air travel before enhancing train services to achieve climate-neutral group travel. By carefully planning infrastructure investments, implementing measures to discourage air travel, and promoting sustainable alternatives, the EU can move closer to its vision of climate-neutral group travel. These findings provide valuable insights for policymakers, stakeholders, and researchers, informing strategic decisions and actions towards a more sustainable and environmentally friendly future for group travel in the EU.

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1. Introduction

Transport is an essential service in the everyday lives of people. Goods and raw materials need to be transported to manufacturers and customers, and people travel all over the world to their work, their families, or enjoy a vacation. To maintain and develop a global economy, transportation is very important. Transportation, especially fast modes of transportation, connect the world (Rodrigue, 2007, Ali et al., 2018). The COVID-19 pandemic had an immense effect on everyday lives and also on the transport sector. Due to the COVID-19 pandemic, the transportation sector was hit hard as way less travel movements were possible, which had negative economic effects (Xu et al., 2021). The pandemic showed that a "well-functioning transportation sector is crucial for each country and for the EU as a whole." (Finger et al. 2022).

Not only literature about transportation shows the importance of the sector, but this is also reflected by the statistics about this sector. The transport and storage sector accounted for 5% of the total gross value added in the EU-27 (the 27 member states of the European Union) in 2019. This accounts for around 624 billion euros. Furthermore, 10.5 million persons were employed in this sector in 2019, and 984 billion euro was spent by private households in the EU-27 on transport related items (European Commission, 2022).

Although the transportation sector is a big part of and contributes a lot to the economy of the European Union, there are also negatives to the transport sector being this large. The transportation sector in total accounts for 23% of the global energy-related CO_2 emissions (IEA, 2022). This shows that the transportation sector is a large contributor to the emission of greenhouse gases (GHG). These total emissions can be divided into the emissions of several transportation modes. In the European Union the large emitters are road transport, aviation, and maritime, which account for 71.7%, 13.4%, and 14.0% respectively to the total GHG emissions caused by the transport sector (European Commission, 2022). A notable statistic is the contribution of the railway sector to the transport emissions. This mode of transport only contributed 0.4% to the total GHG emissions caused by the transport sector in the European Union (European Commission, 2022).

The importance of the transport sector for society on the one hand and the huge emissions caused by this sector on the other hand show how relevant it is to take measures to make this sector more sustainable. A transportation mode that could play an important role in this is the train. The train is seen as a sustainable mode of transportation, as the direct emissions of rail transport are way less than planes (Noussan et al., 2022). Where the total emission by rail transport is only 0.4% of the total emissions by the transport sector, 7% of the passenger kilometres travelled within EU-27 is by rail (European Commission, 2022). The rail network in Europe is for 60% electrified on which 80% of rail traffic is run (Eurostat, 2023a; Eurostat, 2023b). This makes the train a more sustainable mode of transportation compared to fossil fuel powered vehicles, as electricity can be produced sustainable already.

The European Union aims towards a Single European Transport Area (SETA) in which the transportation modes become more uniform throughout the whole EU (European Commission, 2011, Finger et al., 2022). With SETA, EU-countries will be more connected while at the same time the efficiency of the transport sector will increase. This will only be more sustainable however when it is performed in the right way (Finger et al., 2022).

The research performed in this report, is part of the curriculum of the master Industrial Ecology and needs to be relevant for this study program. Industrial Ecology is a scientific discipline that tackles sustainability challenges by taking a comprehensive and systemic approach. It integrates technical, environmental, and social perspectives to study society's material and energy basis, known as its metabolism. By examining this metabolism through a socio-technical systems perspective, Industrial Ecology seeks to identify, design, and evaluate solutions for sustainability problems, as well as their implementation.

The topic of working towards climate neutral transportation within the European Union is therefore a relevant sustainability problem for the perspective that Industrial Ecology has. The transportation system has a technical side in which techniques within means of transportation, and infrastructure are included, as well as a social side regarding travellers and the organisational structure behind the system. This aspect, combined with the negative effects transportation can and does have on the environment, working towards climate neutral transportation is a very relevant topic from an Industrial Ecology perspective.

This research focuses on the ambition of the European Union to work towards SETA while reducing the impact on the environment from the transport sector (European Commission, 2020, Finger et al., 2022). From the literature review performed in chapter 2, a literature gap is identified for intervention pathways on cross border trains. The gap exists because the studies delivering intervention pathways for transport related topics have a broad focus or focus only on one country. Within these studies, multiple transportation modes are taken into account. This makes that there are no studies that formulate pathways with the focus on making the train the main mode of transport in the EU.

Based on this research gap, the main research question is formulated: *What implementation pathways are foreseeable to replace air passenger transport with high-speed rail within Europe?*

To address the research question at hand, backcasting analysis emerges as a highly effective methodology. Backcasting is recognized as a valuable tool for generating solutions to complex problems, particularly within the realm of sustainability (Barrella and Amekudzi, 2011, Dreborg, 1996). Sustainability-related issues are complex, encompassing various factors such as interconnectedness, feedback loops, non-linear dynamics, and the involvement of diverse stakeholders with conflicting interests and values. Additionally, they involve multiple facets, including economic, social, and environmental aspects. Considering these complexities, backcasting analysis offers a strategic approach to tackle sustainability challenges by envisioning a desired future state and working backward to identify the necessary steps to achieve it. By doing so, it allows for the integration of diverse perspectives, long-term thinking, and informed decision-making to create positive change in our society and environment.

This research will explore the possibilities for the development of rail transport within Europe. What are the constraints and possibilities for this mode of transport to become more used instead of other transportation modes? Multiple pathways towards a more sustainable passenger transportation network in Europe, based on rail transport will be developed. These pathways will be constructed using a backcasting analysis.

This research starts with the literature review in which the basis of this research is build, and the literature gap is substantiated. After this, the methods used for answering the research question are explained. Then the results will be presented which are followed by the formulation of the pathways, a discussion about the results, and a conclusion.

2. Literature review

For performing this literature review, literature about passenger transportation, and more specifically replacing aviation with the train within Europe for passenger transportation has been reviewed. The focus for this research was already determined to be on replacing travelling by airplane with travelling by train. This was based on the presumption that aviation contributes a lot to climate change by emitting large amounts of GHGs while the train is seen as a more climate friendly mode of transportation. Both these presumptions were confirmed by numbers on transportation which will be discussed in this literature review as well (European Commission, 2022).

Literature was searched for in the catalogue of Leiden University Library. This is the recommended by Leiden University to use for research conducted by their students. Prompts were used to find literature concerning passenger transportation, replacing aviation with the train, and sustainable transportation. Prompts were used that are comparable to:

(train OR rail) AND ((passenger (transportation OR traffic)) AND (in Europe) AND (compared to OR instead of) AND (air transport)

The articles found by these prompts were selected based on the year of publication to review the more recent literature. Also, the relevance of the articles was rated based on the scope of the research performed, the geographical area, and the methods used. For the first papers, more general publications were chosen. From these initial papers a snowball sampling technique was used to see which other papers were cited often in them and seemed relevant for this literature review.

First, literature about high-speed transport systems is reviewed, and is followed by a review of literature focussed on High-Speed Rail (HSR), the sustainability of transport modes, and policies concerning the sustainability of transportation.

The European Union has as a goal to construct SETA, a Single European Transport Area, in which modalities are connected better with each other, as well as connected transport networks throughout the different countries in the EU (European Commission, 2011, Finger et al., 2022). High speed transport systems are of specific interest to reach this goal. High speed transport systems are defined as transportation systems that travel at high speeds, mostly more than 200 km/h (Janic, 2003). Typical high speed transport systems are Air Passenger Transport (APT) and HSR. These high-speed transportation systems contribute towards connecting more places all around the world and covering the distances in shorter time because of the high travel speeds. This is beneficial for globalisation as the world becomes more connected in a shorter travel time (Rodrigue, 2007). Besides that, high speed travel systems can also be beneficial for sustainable development. With the implementation of the right high speed transport system, traveling can become safer whilst emitting less CO_2, causing less air pollution, and decreasing land-use (Janic, 2003).

The ambition of the European Union to create a SETA, while also becoming the first net zero emitting continent in 2050 (European Commission, 2011, Finger et al., 2022) delivers an interesting case with many challenges. The different options to reach these goals need to be discovered, and the question arises: which transport mode is most suitable to reduce climate impact from the transport sector?

To answer this question comparisons are made between the different high speed transport systems. In several articles performance on several key indicators is analysed to find the most suitable system for the passenger transport industry in the EU. Key indicators for the suitability of transport systems are among others: travel time, generalised transport costs, investments, and sustainability aspects like air pollution, noise and land use. Janic (2003) compares HSR with APT and a maglev train. Key indicators not only include sustainability measurements in this comparison. HSR is seen as the preferable option out of the three, even when it comes to non-sustainable related indicators. APT is seen as the least favourable.

When the attention is focussed on the sustainability aspect of transportation, numbers on transportation for the EU show the advantage the train has over aviation. The numbers show that transport by rail only caused 0.4% of the emissions from the entire transport sector, while contributing 7% of the passenger kilometres and 12% of freight transported in 2019. In comparison, 9.7% of passenger kilometres are travelled by air and only 0.1% of freight, but aviation causes 13.3% of the total GHG emitted by the transport sector (European Commission, 2022). This shows that emissions are way higher for aviation than for rail transport, especially when looking at emissions per transported unit (i.e., CO_2 eq. per passenger kilometre or per ton kilometre). Also, the literature concludes that aviation is more polluting than rail transport when it comes to GHG emissions. Aviation is even seen as the worst transport mode regarding CO_2 emissions. In almost all cases aviation emits the most CO_2 equivalent (Noussan et al., 2022). Figure 2.1 shows the CO_2 equivalent emission factors measured in grams per passenger kilometre for several transport modes. Noussan et al. (2022) have compared many studies measuring well to wheel (WTW) and life cycle emissions by life cycle assessment (LCA). In almost all cases rail emits less than planes and is also emitting less than a lot of cars, the two transport modes that are used more for passenger transportation.
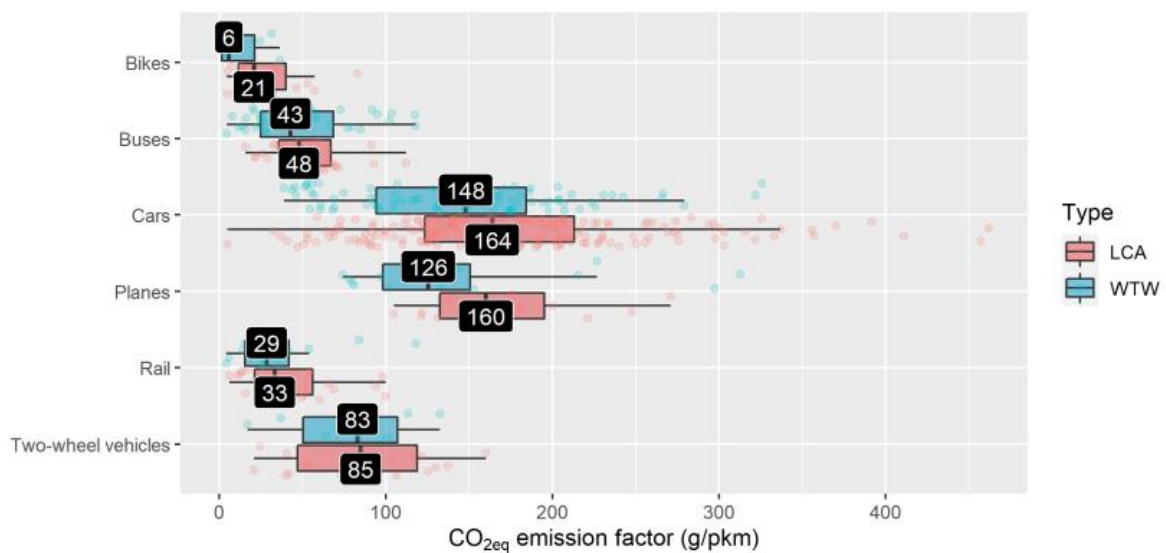
Figure 2.1: LCA and WTW emission factors for different transport modes (Noussan et al., 2022).

Looking at the sustainability of transport modes, the research of Noussan et al. (2022) is not completely representative. For instance, not only HSR was taken into account, but also normal trains while HSR emits more than normal trains (Albalate & Bell, 2012). Also, the energy mix of a country has to be taken into account, i.e., the production ways of electricity whether they are sustainable or not. Choices about changing transport modes have to be made carefully when searching for the most environmentally friendly transport network. Although rail transport shows promising signs of being the environmentally friendly transport option (Janic, 2003, D'Alfonso et al., 2016, Noussan et al., 2022), several factors have major influence on the sustainability of HSR.

The construction of a railway system can be a dealbreaker when looking at the sustainability of HSR (Albalate & Bell, 2012). During the construction of railways costs a lot of energy, and when this energy comes from fossil fuels, more GHGs are emitted. Also, the huge investment costs for the construction of railway are seen as a barrier for using more trains (Albalate & Bell, 2012, Rungskunroch et al. 2021). It is, however, still worthwhile to invest in the construction of a HSR network according to Rungskunroch et al. (2021), because of the environmental benefits HSR has over other transportation modes during the life cycle of the rail network.

Besides the construction itself, also the noise, the land use and emissions of other substances than CO_2 have to be taken into account when assessing the sustainability of a transportation system (Albalate & Bell, 2012). These points indicate that there is a problem in the assessment of sustainability of a transport system, since a uniform terminology for sustainability lacks. Uniform terminology is advised as it enables comparison between modes of transport and prevents greenwashing (Finger et al. 2022). Also, a single measuring unit for emissions can be helpful in comparing modes of transportation (Noussan et al., 2022). This is on the level of which emissions need to be taken into account, i.e., the emissions caused in the several stages of the life of a transport system, i.e., manufacturing, construction, operation, and end of life.

Despite the criticism on some of the environmental impacts caused by HSR, the environmental benefits HSR has compared to APT seems to outweigh them. Therefore, it is understandable that the European Union wants to increase the use of train, triple the length of HSR network by 2030, and by 2050 the majority of medium-distance passenger transport should go by rail (European Commission, 2011).

Realising a modal shift from air to rail depends on several criteria. The most important criterion for passengers is indicated to be the travel time (Adler et al., 2010, Clewlow et al., 2014, Stamos et al. 2016, Brida et al. 2017). Travellers are willing to pay more to reach their destination in a shorter time (Brida et al. 2017). Other factors that are important with regard to the choice of travellers are comfort, safety, and the costs of their journey (Stamos et al. 2016). Because of these factors that determine the choice for travel mode, several studies argue that competition between HSR and APT is possible for routes with lengths from 200 to 2000 km (Milan, 1993, Gleave, 2004, Adler et al., 2010, Albalate & Bell, 2012, D'Alfonso et al., 2016). Gleave (2004) states that HSR has the highest potential to compete with APT on routes between 300-600 km. At these distances, HSR has the highest potential time savings compared to APT. Instead of taking the distance travelled as a measurement, some papers take the travel time to see where competition is possible. As the travel time is most important for travellers, it makes sense to take the travel time instead of travel distance. When looking at travel time, competition of HSR with APT can be successful on routes with a travel time between 1.5 to 4 hours (Dobruszkes, 2011, Dobruszkes et al., 2014, Kroes & Savelberg, 2019).

Examples of successful replacement of APT with HSR can be found all around the world. The introduction of HSR on multiple routes has decreased the demand for air traffic on these routes. In France and Spain, the corridors where HSR is introduced, the majority of the travellers on these routes travel by train instead of the airplane (De Rus et al., 2009, Dobruszkes, 2011, Albalate et al., 2015). Also in Asia, the introduction of HSR on routes up to 1000 km has led to a decrease in air traffic on these routes. Sometimes the flights between certain cities were completely terminated (Park and Ha, 2006, Fu et al., 2012).

Another way of looking at high speed transport systems is to look at HSR and APT as complementary means of transport. For journeys with transfers between flights, it can be interesting to substitute the shorter leg of the journey by HSR. In that case HSR can be complementary as a short-haul service to support a longer-haul airline service and relieving congestion at airports (Clewlow et al. 2012). Because HSR is seen as a more environmentally friendly mode of transportation, the implementation of HSR in journeys with a transfer between flights receives political support in Europe (Aziz et al. 2016). However, replacing short-haul flights with HSR might be just a business opportunity for the aviation sector, and can be negative from a sustainable perspective. When short-haul flights are replaced by HSR, capacity becomes available at airports for longer flights to replace these shorter ones. Long-haul flights are more profitable for airlines, but also a lot more GHGs are emitted during longer flights. When this happens, the implementation of HSR will have a negative impact on the

environment (Dobruszkes & Givoni, 2013). This again shows that it is very complex to make the right choices with regard to sustainability in the transportation system. At the moment that one mode of transportation is replaced by a more sustainable one, there can still be negative environmental effects because for example of an increase in demand, in this case for long-haul flights.

Since the European Union has a positive attitude towards implementing HSR in the EU (European Commission, 2011) it will be interesting to see how this will be done. As the average flight distance within Europe is approximately 1100 km (Adler et al. 2010), many routes are appropriate for HSR as the preferred mode of transport. For these routes further research is necessary to find out what the possibilities are to replace APT for HSR.

The literature review so far indicates that there has been quite some research on the replacing, competing or the collaboration of HSR with APT. Factors of success are discussed both for implementing HSR on certain routes and for competing with APT. What is lacking, however, are studies regarding intervention pathways to reach the goals as stated by the European Union to make rail transport the main mode for medium-distance passenger transport in 2050. To formulate these pathways, a backcasting analysis is seen as a useful method. Several studies argue that a backcasting analysis is a useful tool to tackle sustainability issues (Barrella and Amekudzi, 2011, Dreborg, 1996). Backcasting has a problem-solving approach, which is eminently suitable for wicked problems (Dreborg, 1996) A wicked problem is a complex, systemic, and persistent challenge that resists straightforward solutions. These problems are characterized by high levels of uncertainty, ambiguity, and conflicting values and interests among stakeholders. They are often interconnected with other issues and require a deep understanding of the root causes and multiple perspectives. Addressing wicked problems requires a collaborative and adaptive approach that acknowledges the inherent complexity and uncertainty of the problem and seeks to develop solutions that are robust, equitable, and sustainable over the long-term. A change or transition to more sustainability in the transport sector can be seen as a wicked problem. Furthermore, a backcasting approach has a normative nature, as does sustainability (Quist, 2013).

Several backcasting analysis are performed on transport related issues. Some will be discussed to see what is done in this field of research until now. By doing this a literature gap can be shown that the research performed in this thesis tries to fill.

The Organisation for Economic Co-operation and Development (OECD) has performed a backcasting analysis on environmentally sustainable transport (OECD, 2002). The visions for the backcasting analysis by the OECD for environmentally sustainable transport were set for the year 2030 and pathways were formed. Geurs & van Wee (2004) have reviewed this backcasting analysis from the OECD specifically for the Netherlands. The approach that is taken in both these papers is very broad, and the whole transport system is taken into account. Also, the time period to reach the envisioned goals, i.e., 2030, has almost come to an end, while the need for sustainable transportation becomes only bigger.

More recent backcasting studies for the transport sector include papers from Soria-Lara & Banister (2018) and Camilleri et al. (2021). These studies have a more focused geographical context for Andalucía and Malta respectively. The researchers used the backcasting method for a more focused and a smaller transport area by focussing on national transport, without crossing international borders.

Problems related to sustainability are seen as wicked problems and take long periods to solve (Barrella & Amekudzi, 2011). In order to solve these problems, backcasting is seen as a useful tool (Dreborg, 1996, Geurs & van Wee, 2004, Barrella & Amekudzi, 2011). Backcasting is an action-

oriented approach of analysing a problem which makes it useful for solving problems. (Barrella & Amekudzi, 2011). Dreborg (1996) argues that backcasting is a useful tool when:

- A problem is complex and affects many sectors and levels of society.
- A major change is needed, as marginal changes are not sufficient.
- Externalities play a large part in the problem and the market fails to address them.
- There is a long enough time horizon that allow for deliberate choice.

All these conditions are all relevant when looking at sustainability for the transport sector. Therefore, a backcasting analysis will be performed in this research.

Performing this literature review has identified a literature gap for intervention pathways towards a sustainable transportation sector in the EU in which the train plays an important role. The modal shift from air to rail passenger transportation seems to be a good step towards sustainable transportation, as the train is seen as a more sustainable mode of transportation. Therefore, the main research question will be:

What implementation pathways are foreseeable to replace air passenger transport with high-speed rail in the European Union?

3. Methodology

3.1 Backcasting

The backcasting approach has been described in several publications. Proper overviews of the different methods for backcasting are given by Quist (2013) and Barrella & Amekudzi (2011). The essence of the backcasting approach is that one or multiple future scenarios or desired future visions are formulated. These scenarios or visions are the starting point that make it possible to work all the way back in order to develop pathways to reach these visions. The way in which the backcasting analysis will be performed depends on the goal and scope of the research, and the possible participation of stakeholders in this analysis (Barrella & Amekudzi, 2011, Geurs & van Wee, 2004, Quist, 2013).
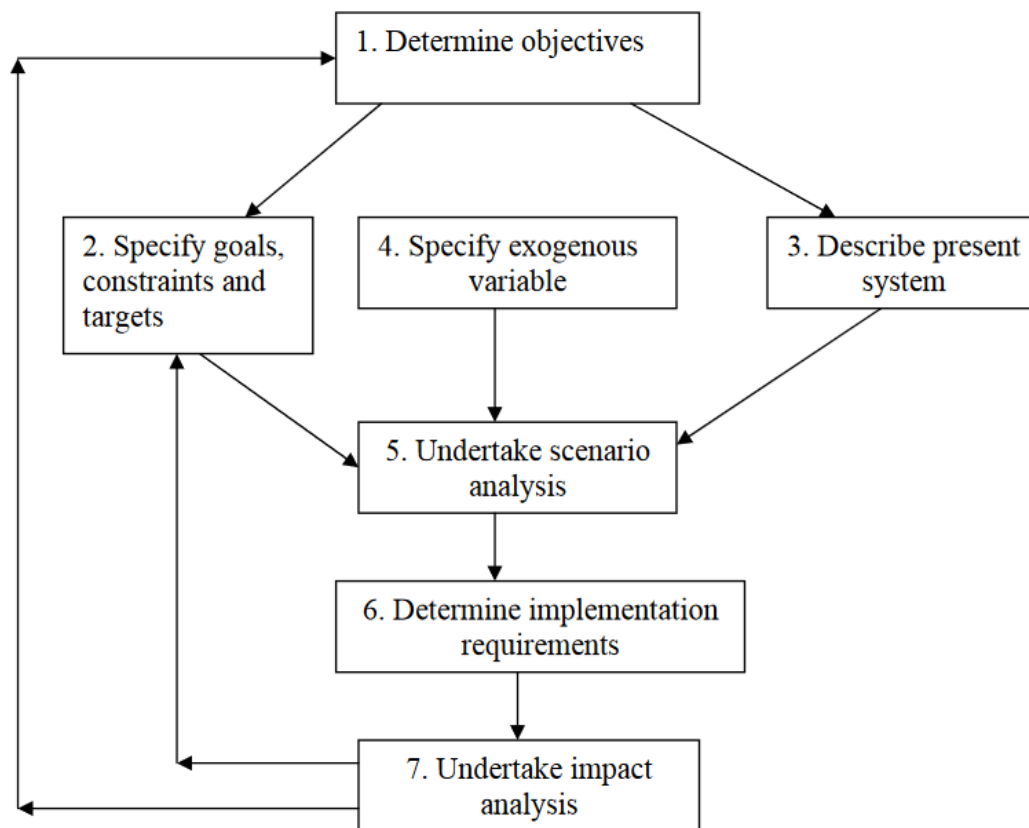
Figure 3.1: Backcasting framework proposed by Robinson (1990) as shown by Geurs and van Wee (2004).

One of the first people who created a framework for backcasting analysis was Robinson (1990). Geurs and van Wee (2004) have described this framework which is graphically interpreted in Figure 3.1. In this framework the steps are explained as follows:

1. The objectives of the research are formulated. What is the reason for the backcasting analysis?
2. What are the goals and targets of the future vision?
3. What is the current state of the system that will be researched?

4. Exogenous variables are discovered, i.e., estimates about economic growth, demographics, stability of prices of products, etc.
5. Scenarios are formulated to work towards, as well as midpoints.
6. What needs to be done to work towards these scenarios? Aspects on behavioural, institutional, and policy changes among others are formulated.
7. The impact of the implemented pathways is analysed.

After this, multiple frameworks have been created by different people or organisations. The OECD and Quist are two of them. The OECD has come up with their so-called environmentally sustainable transport (EST) approach and they use this approach to form guidelines towards EST (OECD, 2002). Three steps are taken in this approach:

1. Scenarios are formulated for a sustainable future.
2. Quantifiable targets are formulated towards this sustainable future.
3. Working back from these scenarios and targets towards the present to formulate which actions are needed to reach this sustainable future.

The OECD emphasizes on the fact that they use sustainability in a very broad sense. The future needs to be environmentally, socially and economically sustainable. To reach this, they use their EST approach, as this approach focusses much more on sustainability than other, more conventional methods like forecasting (OECD, 2002). Because the EST approach combines environmental, social, and economic sustainability, this approach should lead to pro-active policy development to fill in the existing policy gap in order to reach the sustainable future scenario (OECD, 2002).

Quist (2007) shows another framework for a backcasting methodology, which is based on other frameworks for backcasting and scenario building. In this framework five steps are followed. These are shown in Figure 3.2.
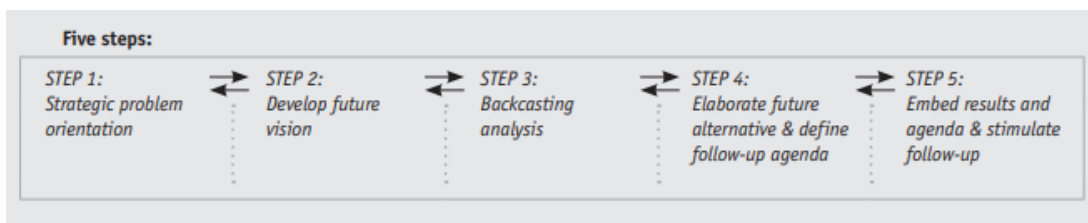
Figure 3.2: Framework for backcasting analysis (Quist, 2007)

The framework from Quist is used for participatory backcasting. This means that in the research the involvement of stakeholders is very important in the research and the formulation of the vision(s) as well as for the pathways.

These three examples of frameworks for backcasting are all very similar by following similar steps in a similar order. Geurs and van Wee (2004) note that the framework proposed by Robinson (1990) is not a set method that needs to be followed exactly when performing a backcasting analysis, it is just an outline of what a backcasting analysis could look like. This also holds for the frameworks from the OECD (2002) and Quist (2007). Using such a framework will be a guideline for working on a backcasting analysis and in order to come up with pathways towards future scenarios that in general have a focus on sustainability.

Important aspects to consider in a backcasting analysis are the goals of the study. These goals can vary from creating normative future visions and analysing them on environmental improvement, to putting attractive future visions on the agenda of policy makers or encouraging stakeholders to reach

the future vision through a follow-up agenda with actions that can be taken towards this vision or creating stakeholder awareness among others. In this study, the goal of stakeholder awareness, their opinions, and the exploration of possible pathways towards the future scenario(s) will be dominant. As Quist (2013) states that the framework proposed by Quist (2007) can be used in a broad way for backcasting analysis with different goals, this framework will be the basis for this study. There are some other considerations about the choice for this framework. The framework of Quist is very clear, with sub-steps for the five main steps to follow along more easily. The fact that the researcher himself had earlier experience with this framework plays a role, as this framework is familiar, and less time is needed to get acquainted.

Another note on backcasting studies, is the lack of attention on the time-paths towards the vision that is created in the backcasting analysis (Geurs & van Wee, 2004). The framework proposed by Quist (2007) gives this part of backcasting more attention by elaborating on the pathways in step 4 (Figure 3.2). This makes the framework by Quist (2007) more suitable for the research in this thesis, as the focus will be on the formulation of intervention pathways.

As the backcasting framework can be tailormade for the goal and scope of the study, the right methods can be chosen for this particular research. The choices made for the formulation of the backcasting framework used for this research will be explained in chapter 3.2.

3.2 Framework

The framework that was used in this study is based on Quist (2007). Quist (2007) follows five main steps and these steps have been followed in this research as well. Adjustments have been made to these steps to match the scope of this research. The steps shown in Figure 3.2 are the basis of the framework and sub steps will be explained per step in the following section. The focus of this research is on the formulation of intervention pathways and therefore steps 3 and 4 are the most important steps for this research, and have been performed more elaborate. The other steps are also taken, but less elaborate compared to steps 3 and 4. This choice is made because of the already existing vision from the European Union for the train, which makes the need for an elaborate step two less needed for this research.

Step 1: Strategic problem orientation.

The strategic problem orientation that has been performed in this research is a little less detailed and extensive as the one described by Quist (2007). This choice has been made as the focus in this research has been on the backcasting analysis and the formulation of the intervention pathways. Nevertheless, a brief overview of the current state of the transport system is given in chapter 2, as well as a description of the sustainability issues. For this, statistics are used from Eurostat that give a good insight in the state of the transportation system in Europe.

From the literature review, the sustainability issues of the transportation system became clear already. The aim of the European Union to become climate neutral, with as a part of that aim, making the train the main mode of transportation within Europe for group passenger transport was already an interesting beginning point. Therefor the focus was shifted towards the pathway formulation which was not done yet via backcasting.

Step 2: Develop future visions/scenarios.

This step builds on the results from step 1. Future visions/scenarios were formulated based on the literature review performed for step 1, as well as reviewing plans from the European Union that are already formulated as future goals. Future visions were formulated based on already existing visions together with findings from literature about what should be a desirable future to work towards. These visions are described in chapter 4.2.

As this vision was already formulated by the European union to some extent, this step was not performed as elaborate as done by Quist (2007). By focussing on the later steps of the backcasting analysis, the focus was more on how to reach an already existing vision.

Step 3: Backcasting analysis.

In the backcasting analysis, pathways were formulated towards the future visions formulated in step 2. Working back from these future visions to the present, three questions were asked to come up with possible solutions to reach the visions formulated earlier: What, How and Who? A more elaborate description of the answers to these questions is discussed in the following section. The complete questions that have been asked are:

- *What are the needed changes to reach the future vision?*
- *How can these changes be achieved?*
- *Who are involved or needs to be involved in these changes and what should they do?*

The WHAT question can be asked with respect to several aspects that are important in realising a transition or reaching the formulated future visions. These aspects are:

- Technological changes

This relates to the technologies that need to be invented, improved, or implemented, to reach the future vision.

- Cultural and behavioural changes

This relates to the more social side of reaching the future visions. What behaviour is needed and what cultural aspects play a role in reaching the future vision.

- Structural changes

This also includes organisational changes and the policies needed for reaching the future vision and includes rules and regulations that need to be put into place.

The HOW question builds on the WHAT question and seeks to answer how the changes that are needed will be put into a strategy of reaching the future vision. How will these individual changes be implemented and work together to establish a transition towards climate neutral transportation within Europe, and a modal shift towards the train?

The WHO question results in a list of stakeholders that are needed to make these changes or are involved in the transition in another way. It gives insight as well in their role in reaching the future vision.

To answer the questions stated above, the choice has been made to gather input from experts with several areas of expertise. Expert knowledge was needed on the topics passenger transportation, sustainability, sustainable transportation, and policy making. To gather this information, semi-structured interviews with experts on these topics were conducted. Experts were contacted from the

list of involved stakeholders. The interviews with experts delivered the information to answer the What, How and Who questions stated above. These findings are discussed in chapter 4.3.

Step 4: Elaborate future scenarios.

Based on the information gathered during the interviews, and the answers formulated for the What, How and Who questions stated in step 3, pathways have been formulated towards the vision formulated in step 2. These pathways and the desirability of reaching the formulated future vision is discussed in chapter 5. The pathways were based on the results from the semi-structured interviews and the input from the researcher by linking the mentioned topics during the interviews.

Step 5: Embed results and stimulate follow-up.

The interviewed participants received a copy of the final report as they had contributed towards the results. Also, the relevance of the results for their profession, especially for the policymakers, can be useful and lead to a change. As the results from this research can contribute as a policy and decision-making support, sending this report to the experts, among which were policymakers themselves, this research can be a basis to support their decisions concerning transportation related sustainability issues.

3.3 Interviews

In step 3 and 4 of the backcasting analysis, semi-structured interviews were used to gather expert knowledge as basis for the formulation of the pathways towards the future vision that was formulated in step 2 of the backcasting analysis. Semi-structured interviews were chosen as method for qualitative data gathering because they provide enough structure to focus on relevant topics, while still providing participants with room to give input from their own experience and introducing possible new topics (Galletta & Cross, 2013). This makes the semi-structured interview a relevant method for this research, as discovering new topics and possibilities is one of the deliverables of this research.

Based on the preliminary literature review, and results from step 1 and 2 of the backcasting analysis, the interview protocol has been formulated. Guidelines from Galletta & Cross (2013) were used to shape this protocol and choose the right participants for the interview. These guidelines state three segments to build the interview. Start with an opening statement in which the topic of the research is introduced, and a consent form will be signed by the participant. This to make clear that the participant can opt out of questions, or the whole interview at any time, as well as information about the privacy of the participants. For this interview, the participants will be anonymised, but their field of expertise will be known. After this the interview follows, divided in three segments:

Segment 1: Very broad open questions will be asked. By doing this, the experience of the participant is used to gather information without going to deep into more theoretical questions. The questions are related to the research topic i.e., climate neutral transportation, but the participant will have a lot of freedom to express their experience and believes. During these questions in segment 1, important points made by the participant will be written down by the interviewer in order to ask in more detail during following segments.

Segment 2: Questions that are more related to the theory used, i.e., the future visions formed in step 2 of the backcasting analysis, are asked. This builds on the answers given in segment 1. Diving deeper into the subject can be done in this segment by means of questions that have been formulated beforehand, making the interview more structured, or by using directed probes about important points made by the participant in segment 1.

Segment 3: This segment is used as concluding segment. Topics that are not yet clearly answered can be dived deeper into. Asking the participant if they want to add something by themselves will be done in this segment of the interview as well.

This protocol is just a guideline, since a semi-structured interview can differ depending on the participant. The general idea of using three segments has been used in formulating the questions for this interview. The structured questions were equal for all the participants, but during the interview the focus shifted per participant to different topics depending on the expertise of the participants and the topics mentioned by them. The interview protocol can be found in Appendix A.

Besides formulating the protocol for the interview, itself, participants were contacted. The choice of participants was dependent on the topic of the research and the information asked from them. For this research, participants were needed with expert knowledge about the following topics:

- Sustainability
- Transportation
    o Passenger transportation
    o Rail
    o Air
- Policy making
- Behavioural change

People with an academic background, a policy-making background or working in the transportation business can all deliver relevant input from different perspectives. To gather sufficient amounts of information for this research, ideally the number of participants is chosen until the saturation point is reached at which no new topics are introduced by new interviews (Galletta & Cross, 2013). Because of time constraints this could become a problem, in which case the saturation point will not be reached. If this is the case, topics that are not yet, or not sufficiently discussed in the interviews will be identified and listed for further research.

A firsts group of participants has been contacted based on their job and their expertise. They were asked to reflect on their knowledge needed for this research. Furthermore, a snowballing method was applied by asking contacted people whether they knew people with relevant knowledge who could be contacted.

The data analysis of the interviews has been done by transcribing audio-recordings of the interviews as literally as possible. The transcribed interviews have been coded for analysis which will be explained in the next section.

3.4 Coding of the interviews

The transcribed interviews with feedback have been coded to gather common topics, opinions and useful information for the formulation of the pathways. To start the coding process, coding has been

done both in a concept-driven manner as well as in a data-driven manner. With the concept-driven way of coding, the starting point was a list of codes before the start of coding the text. As this research has a clear scope, some topics that would come up during the interviews were predictable and were written down as possible codes beforehand. These codes were based on prior knowledge about the topic gained during the literature review. Topics covered by these codes included sustainability, travel time, travel costs, and infrastructure, as these were main topics in literature, and mentioned often during the interviews.

The data-driven way of coding was used in the way of inventing new codes during analysing of the text. This way, topics that were not yet pre-determined but were relevant for the research could be included. Parts of the text were reviewed, and topics that were mentioned in that part of the text that could possibly be mentioned more often in that interview or other interviews were converted into a code. This was done in a way that this code could possibly be used more often on other parts of the transcribed interviews. In this way, matching topics could be found easily throughout different interviews.

For coding the documents, Atlas.ti was used as a coding tool. Within this program, coding was performed, as well as the analysis of the frequency of hits of codes and by whom it was mentioned.

The codes used and applied to parts of the text were compared afterwards in order to check whether the code applied fitted in the part of transcribed interview. This process continued also during the analysis of the codes and deducting the results. Some codes were describing the same topic in another interview and could be merged with each other after finishing the coding process.

The final list of codes applied to the transcribed interviews was analysed in order to group the codes into certain topics. In this way, the codes were put together in groups of codes, for instance, relating to aviation or train related topics. Also, groups of codes were made for the stakeholders that were involved in those topics.

3.5 Interviewees

Ten people have been interviewed in 9 interviews. People were contacted based on their profession. The first group of contacted people were identified by searching for academics with relevant knowledge, or policy makers working at departments that were relevant for this study. Professions that were relevant for this research needed to have knowledge of, or experience with transportation, sustainable transportation and/or changing human behaviour. People were contacted working at universities, European and Dutch transport ministries, and strategists working for rail operators.

When people were contacted, they were asked if they wanted to participate, whether they thought they had the right knowledge to participate, and if they knew other people that also could contribute with their expert knowledge. By doing this, snowball sampling was applied in which more people could be contacted for participation. Also, people that were contacted, but had not the right expertise to usefully contribute to the research were eliminated but could still contribute by connecting other people to the research.

In Table 3.1 the professions and/or areas of expertise are shown for the participants. The participants are kept anonymous as agreed in the interviews and only their area of expertise is relevant for the legitimacy of their answers.

Four academics, three policy makers, two experts from the private sector and a behavioural expert were interviewed. Their area of expertise was always linked to transport, planning, and/or the train. Some expertise on aviation was also present, but always in combination with expertise on the train, or transport in general.

Table 3.1: Area of expertise of the interviewees.

Interviewees	Area of expertise	
1	Working in private sector in freight transport planning and overarching sustainability commission for the freight transport sector.	
2	Academic on long distance travel behaviour.	
3	Academic on long-term strategic transport management.	
4	Academic on sustainable transport for tourism.	
5	Academic on sustainable urban mobility.	
6	Policy maker for transport in the green deal in the European Commission.	
7	Strategist at prorail.	
8a	Dutch policy maker for public transport and rail.	Work together on air rail agenda
8b	Dutch policy maker for aviation sector.	
9	Behavioural expert with experience of working for transport department of government.	

4. Results and findings

4.1 Strategic problem statement

In chapter 2 a literature review is performed in which the current state of the transport system is discussed as well as the sustainability issues of the system. The transport sector is responsible for 23% of the energy-related CO2 emission worldwide (IEA, 2022), which makes it a very polluting sector. Furthermore, what became clear is that aviation, maritime and road transport are the large contributors to GHGs emitted by the transport sector, while rail transport is emitting a fraction of these other modalities (European Commission, 2022). What also became clear is that the train is emitting in almost all cases less GHGs than airplanes do which makes it a more sustainable transportation mode (Noussan et al., 2022). From this state of the system, it makes sense to replace travelling by airplane with travelling by train from a sustainable perspective. For the formulation of the future vision, described in chapter 4.2, the starting position is to replace aviation with rail transport for passenger transportation. This modal shift will be a part of working towards sustainable transportation and the EU becoming climate neutral.

4.2 Future vision

As is shortly described in chapter 4.1, the transportation sector delivers a major contribution to climate change by emitting large amounts of GHGs. Based on this sustainability issue together with the perspective of Industrial Ecology to address sustainability issues, a vision towards a solution for this issue can be made. For the formulation of this vision, existing ambitions and goals of the European Union are examined, as well as literature sources to support these goals.

Several documents of the European Commission communicate goals and several actions towards a more sustainable future (European Commission, 2011, European Commission, 2018, European Commission, 2020, European Commission, 2021). One of the goals often mentioned in these documents, is the goal for Europe to become a climate neutral continent in 2050. To reach this goal, several targets are set, including targets regarding the transport sector. In 2011, the European Commission formulated the target of a 60% reduction of GHG emissions from the transport sector in 2050 compared to the levels in 1990 (European Commission, 2011). Later on, the goal of the European Commission was to reduce these GHG emissions by 90% in 2050 (European Commission, 2020). To reach these goals, the European Commission sees the increased use of the train as mode of transportation as one of the options. The train is regarded to be a more environmentally friendly option, and numbers on GHG emissions per passenger kilometre support this view (Noussan et al., 2022). Therefore, targets to shift transportation to the train are also formulated, complementary to the targets on GHG emissions. In 2030 the HSR network in Europe should be tripled and in 2050 the majority of medium haul passenger travel has to go via rail. (European Commission, 2011).

The European Commission already formulated a long-term strategy for a climate neutral EU in 2050 (European Commission, 2018). Several pathways are proposed in this strategy, and these pathways combined would lead to 90% reduction in GHG emissions in 2050. Since this is not sufficient to reach climate neutrality, the pathways need to be more ambitious, or the focus needs to be on other aspects of working towards sustainability.

Therefore, the vision needs to be more ambitious than the one stated by the European Commission for the transport sector. Net climate neutral transportation needs to be the goal in 2050. As this research will focus on the role of HSR and trains in order to become net climate neutral, the vision will focus on this aspect. The vision for the backcasting analysis will be:

In 2050 the train will be the main mode of transportation for group traveling within the European Union and is a climate neutral way of transportation.

This makes the vision more ambitious than the one formulated by the European Commission. Not only will the train be the main transport mode on medium long distances, but also on longer routes within the European Union. Furthermore, travelling by train has to become climate neutral. This to be in line with the ambition of Europe becoming a climate neutral continent and reducing GHG emissions of the transport sector with 90%.

4.3 Interviews

What are the outcomes of the interviews?

The interviews that were performed for this research were formulated around the vision of making HSR, or train in general the main mode of transportation for passengers within Europe in 2050. The goal of the questions in this interview was to gather expert knowledge from the participants about reaching this vision. Which interventions can be done by whom to reach the vision of making the
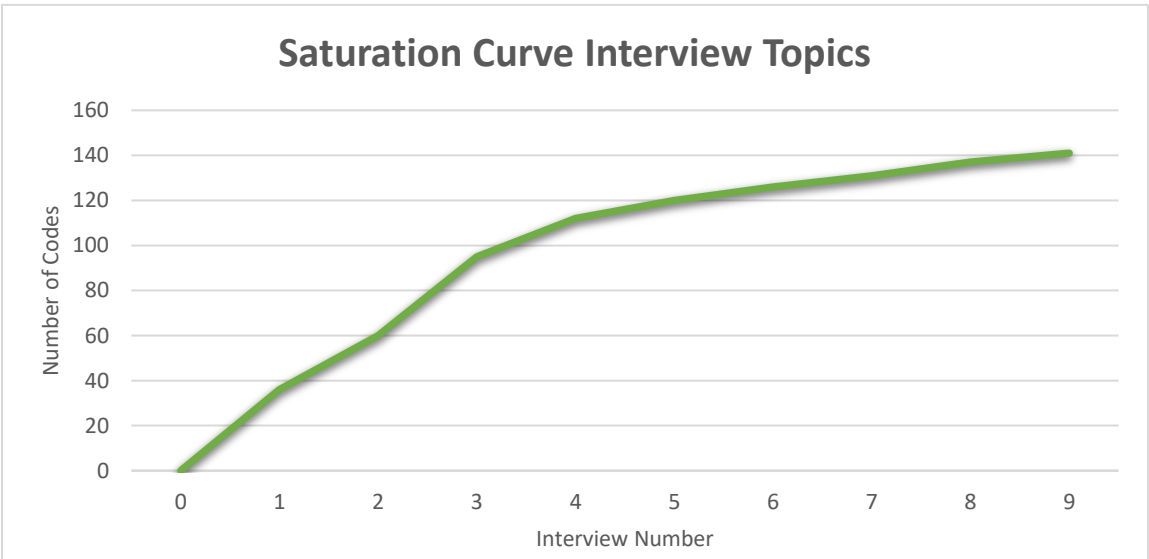
Figure 4.1: Saturation curve of topics mentioned by interviewees.

train the main mode of transportation throughout the Europe Union. Nine interviews with ten people have been conducted.

A saturation point for new introduced topics is being approached within these 9 interviews which is shown in Figure 4.1. This figure shows that conducting more interviews will not lead to more new data and new topics, as the curve is flattening. Possible missing data will be discussed in chapter 6.

The first and most important outcome of these interviews is that it will be very difficult to reach this vision. Even with drastic interventions it is questionable whether this vision will be reached. All participants indicated that in the given timeframe of 2050 it is very difficult to reach this goal, since

the necessary changes are drastic and take a long time to implement. Furthermore, not all the participants were convinced that making the train the main mode of transportation was a desirable vision at all to pursue. Interviewees 3, 4, 5, 8a and 8b were sceptical about the desirability of this vision. The main points they presented for this opinion were the large amount of GHG emissions caused by construction and maintenance of rail infrastructure (interviews 4, 5, 8), the high costs of construction and maintenance of rail infrastructure (interviews 5, 8) and the possibility for aviation to become climate neutral in the future. This last point would make the investments in rail infrastructure seen as sunk costs. Aviation becoming climate neutral as a realistic solution towards climate neutral transport was also mentioned by other participants who were more optimistic about the vision (interviews 3, 4, 5, 6, 8). Although there was no consensus about making the train the main mode of transportation, there was consensus about the need of making transportation more sustainable. Also, the positive contribution of travelling by train as a means towards climate neutral transportation was mentioned by the participants, most specifically by interviewees 4 and 8a.

The aspects of reaching the vision, or at least work towards a more sustainable transport network can be categorised in three categories of questions: WHAT, WHO and HOW. This is consistent with the questions stated for step 3 of the backcasting framework which was described in chapter 3.2. In the next section these categories will be further discussed based on the conducted interviews. The topics mentioned during the interviews can be found in Appendix C. The topics are shown there with corresponding code names used in the interviews, which interview, and how often they were mentioned.

4.3.1   WHAT are the needed changes to reach the future vision?

In this section the needed changes the interviewees have indicated to be necessary to reach the future vision are discussed. How these changes can be realised will be discussed in chapter 4.3.3. The short and summarising answer on the WHAT question, is that it is necessary to make travelling by train competitive with other modes of transport, mainly being airplane and car. At this point in time, other modalities for international travel have a competitive advantage compared to the train. These advantages are the ease of use, comfort while travelling, time spent to reach the destination and the most important one, the costs of the journey. These aspects can be described as generalised transport costs. Travelling by train is in most cases slower than travelling by airplane, booking tickets is far more difficult for an international train trip compared to booking a plane ticket, and going by car or by airplane is often cheaper than going by train to the same destination. To level this competitive playing field, interventions can be done on several sides. These will be categorised in, *train*, *aviation*, and *transport in general.*

All the interventions that are needed to reach the future vision can be summarised as levelling the playing field on the so-called generalised transport costs for the different transport modalities. This helps to make the train a more attractive alternative for the transportation modes that are used the most at this point i.e., airplane and car. In Table 4.1 the main topics that emerged from the interviews that will be discussed in this section are shown with the number of times they are mentioned and in which interviews.

Table 4.1: Most mentioned topics from the interviews.

Topic	Times mentioned	Interviews

Aviation needs to become more expensive	35	1,2,3,4,5,7,8,9
Use the existing rail network more efficiently	29	4,6,7,8
Train tickets easier to book	15	1,3,4,6,7
Construct more rail	15	3,4,6,7,8
Creating sustainable aviation	13	3,4,5,6,8
Electrifying rail and producing the electricity sustainably	12	1,3,4,8
Train needs to become cheaper	10	1,6,7,8,9
Choose closer to home destinations	9	3,4,8
Travel less	6	3,5,8

Train

For the interventions on the part of the train, a distinction can be made between interventions regarding the rail infrastructure, and interventions on soft factors like comfort, ticketing, information, ease, etc.

When looking at the rail infrastructure, it became clear that there are several barriers for the construction and maintenance. These are shown in Table 4.2. Because of these barriers, several interviewees pointed out that an adequate path should be a more efficient use of the existing rail network before constructing new rail (interviews 3, 4, 6, 7, 8). The construction of new rail is still seen as a useful intervention to increase the use of the train, but it is not the first thing that needs to be done in the transition towards making the train the main mode of transportation. Also, research needs to be done on which routes new rail can really be a useful addition to increase the use of trains (interview 3, 4, 6, 8). The introduction of night trains on international routes, possibly travelling with HSR speeds, can increase the capacity of the existing rail network (interviews 2, 4, 8, 9).

Table 4.2: Codes from interviews concerning the barriers and cons of constructing train infrastructure.

Code name	*Times mentioned*	*Interviews*
Construction and innovation of infrastructure for train takes a long time	10	1,2,5,7,8
Construction of rail infra causes lots of GHG emissions	6	4,5,7,8
The land use of rail infra is big and can be a problem	6	7,8
Suppliers of construction materials for rail need to become sustainable as construction is very bad for environment	4	1,4,7,8
Construction and maintenance of rail infrastructure are lots of people needed for	3	1,7

Construction and maintenance of rail infra specialistic knowledge is needed	3	7
Construction and maintenance of infrastructure is very expensive	3	5,8

The rail network in Europe consists of the national networks of every country, and between these national networks differences in track and rail systems exist. These differences should be minimalised and in the optimal situation the rail network of Europe has uniform rail systems and components throughout every country (interviews 1, 7). With this uniform network, less time is lost during an international train trip at the borders to change the train for a different rail network in that country.

The train is already seen as a sustainable mode of transportation when the infrastructure is in its place. This is because the train can be electrified, and the electricity can be produced by sustainable sources. This is not yet the case in all the countries of the European Union and therefore electrification of the European train network is something that can be a focus point to increase the sustainability of the train. Another aspect that is mentioned is the improvement of the production of electricity to be more climate neutral by generating it with solar panels, wind turbines and other sustainable sources (interviews 1, 3, 4, 8). Other options to decrease the use of fossil fuels by trains, are hydrogen trains or battery trains, but these are less preferable because of technical barriers at this point in time (interview 4, 8). Making the train more sustainable is not necessarily something that will increase the use of trains, but it will help in working towards the bigger goal of reaching climate neutral transportation. It could help level the playing field when it comes to the price of travelling. When one has to pay for unsustainable ways of transportation for the GHGs emitted, the train will have an advantage when it is sustainably electrified.

Besides the infrastructure, the generalised transport costs are an important aspect to take into account. With regard to these generalised transport costs, a distinction can be made between money, time and other factors. These other factors include among other things information, comfort, perceived safety, and ease of booking. Based on these generalised transport costs, people make their decision which modality they choose for their travels (interview 3). Time and money are seen as the most important aspects and the interviewers mentioned money the most. Therefore, the price of train tickets should become lower (interviews 1, 6, 7, 8, 9). With regard to time, it is not only the time from station to station that is essential, but also the door-to-door time, and whether or not there is a transfer between trains. Time spent in a vehicle is perceived more positive than time spent waiting on the station before or after a trip, or during a transfer (interview 3). To decrease the time, especially on long international routes, the number of stops at small stations has to be reduced (interviews 4, 8), and when transfers are necessary, the waiting time needs to be reduced in order to achieve a more positive travel experience (interviews 1, 4, 9).

From the other factors in the generalised transport costs, besides time and money, the booking of tickets is mentioned many times. The booking system for international train tickets does not function properly, especially compared to the booking systems for plane tickets. It is essential that the booking of international train trips becomes easier. Also, the fact that passengers have an obligation to reserve train tickets before they travel internationally is something that needs to be reconsidered (interview 2). In order to be certain to have a seat, passengers have to book their train tickets long in advance, also because the capacity in trains is low. This obligation is missing in national train trips, which makes travelling by train more accessible. This is something that needs reconsidering.

It is evident to first look at the improvement of these soft factors before constructing new rail infrastructure, as these soft factors are easier to implement. Implementation of these factors will not take as much time as the construction of a new rail line and will have a faster impact on reaching this vision especially on the short-term (interviews 1, 3, 4, 6, 7, 8).

Aviation

As this research is focussed on replacing aviation by train, changes can be made on the aviation side to increase the use of trains. First of all, the easiest incentive is to make aviation far more expensive for travellers. The choice of modality is partly based on the costs of travelling and the competition with rail is not fair, considering the cheap tickets passengers can buy to reach certain destinations by airplane. Increasing the price of plane tickets is mentioned to be the most important change with possibly the biggest impact (interviews 1, 2, 3, 4, 5, 7, 8, 9).

Replacing flights by train is mainly possible on shorter trips. For longer flights, especially intercontinental flights, or flights to islands, it is more difficult or sometimes even impossible to replace the plane by train as these places cannot be reached by train (interviews 2, 4, 5, 6). When such a long flight consists of a shorter flight as one of the legs of this journey, this shorter flight can be targeted to be substituted by train (interviews 1, 6, 8). To make this multimodal transfer more easy, integrated baggage transfer can be put into place (interviews 6, 8). Also, the presence of a (HSR) station in the vicinity of an airport can benefit the ease and comfort of a transfer between plane and train. Making this multimodal transfer easier and making airports more accessible by train does have downsides that need to be considered. The slots of the short flights that are replaced by train can now be used by airlines for longer, intercontinental flights. This is not beneficial from a sustainable perspective, as longer flights emit far more GHGs than shorter flights (interview 3, 4, 8). The accessibility of the airport could lead to an increase in bookings for flights when it is easier to reach the airport (interview 3).

When looking at the bigger picture of making the transport sector climate neutral, investments have to be made to make aviation a more sustainable mode of transportation (interviews 3, 4, 5, 6, 8). Flying is a very efficient way of transportation as less infrastructure is needed and travel speeds are high. When aviation becomes climate neutral, it will be a very useful way of transportation. There is an interesting comparison between climate neutral flying and the construction of new railway, both being processes that take a lot of time. Choices need to be made between the investments. For short-term progress towards climate neutral transportation, the number of flights has to be reduced as long as they are not sustainable. Long-term speaking, it is very interesting to investigate aviation techniques that are sustainable in order to work towards climate neutral transportation.

Transport in general or multimodality

Table 4.3: Codes about multimodality and door-to-door travelling.

Code name	Times mentioned	Interviews
Multimodal traveling is needed to reach your destination and to spread the load on the transport network	5	5,6,8
Transfers from station or airport to final destination are important	2	3,4

The complete door-to-door travel time has to be better for train	4	3,7
Optimise the different modalities and let them work together (multimodal)	3	8
Multimodal transfers need to become easier (airplane to train)	3	6,8
Destinations can choose where to build an attraction or provision	1	3

Interventions for transport in general are needed for the train to become the main mode of transportation, as most passengers use multiple modalities during a trip to travel from door-to-door. Table 4.3 shows the topics mentioned about multimodality and door-to-door travelling. The interviews regarding these topics clearly show that the final kilometres from an airport or train station often have to be travelled by another modality like busses, cars, or bikes for example, to reach the final destination. The transfer between different modalities have to become easier (interview 3, 6, 7, 8). When focussing on the train, it should be made easier to travel the last kilometres from a train station to the final destination, for example by means of the availability of shared mobility, taxis or the station being close to key destinations (interviews 3, 6, 7, 8).

Another important aspect of a modal shift from airplane to train, or a change in travel behaviour in general, is an alteration of the choice of destination the passengers make, or even considering the option not to travel at all in certain instances. A distinction can be made between two groups of travellers: work related travels and recreational related travels. For work related travels, the destination in most cases is pre-determined and cannot be changed. However, it is possible, to consider not to travel to the office, a meeting with a client or to a convention, but to work from home or meet online. By doing this, less travelling is needed (interviews 3, 5, 8).

For the recreational related journeys, it will be more difficult not to travel. People want to go on a vacation or visit a city during a city trip to see something from the world and to be away from home. A choice in destination however can make a difference. Certain destinations are very remote and can only be reached by airplane (interview 2, 3, 4). Therefore, a choice for destinations closer to home will make the train a more competitive travel mode compared to the airplane when looking at time spent travelling. A behavioural change is needed for both travelling less and choosing other destinations closer to home and that are reachable by train (interviews 2, 3, 4, 8).

Another aspect that also needs to be established is the collaboration between organisations, businesses, academia, governments and the public. A large number of stakeholders is involved, and they all have a role to play (interviews 1, 3, 5, 6, 7, 8). These roles will be further discussed in the section about WHO. Many interventions that will be discussed require collaboration between two or more stakeholders. At the moment this collaboration is not taking place or is not properly coordinated. Strong leadership is required to establish a transition towards climate neutral transportation (interviews 2, 3, 4, 6, 7, 8, 9). For quite a number of the interventions that are mentioned and will be mentioned in following sections, people need to change their behaviour.

4.3.2 WHO are involved or need to be involved in these changes?

From the interviews, several stakeholders were identified and accordingly the level of importance these stakeholders have in reaching the formulated vision. The stakeholders will be discussed in the order of the most to the least important according to the interviews. The importance is based on how often the stakeholders were mentioned in the interviews and on the number of interviews they were mentioned. This is shown in Table 4.4. In Figure 4.2 an overview is given of the five main stakeholders. The figure also shows what they could do in order to reach climate neutral transportation and make the train the main mode within the European Union.

Table 4.4: List of stakeholders mentioned in interviews.

Stakeholder	Interviews	Number of interviews	Times mentioned
Governments	1, 2, 3, 4, 5, 6, 7, 8, 9	9	76
Public/users	1, 2, 3, 5, 6, 7, 8, 9	8	45
Rail operators	2, 3, 4, 6, 7, 8	6	40
Businesses	1, 3, 5, 6, 7, 8, 9	7	19
Airlines/airports	2, 3, 4, 5, 7, 8	6	15
Tour operators/third parties/marketing	1, 3, 4, 6, 8	5	16
Manufacturers	1,4,7,8	4	8
Academia	3, 4, 5, 6, 8	5	6
Destinations	3, 4, 5	3	10
Overarching organisations for sectors	1, 3, 6, 8	4	6
Behavioural experts	1, 9	2	7
Aviation lobby	3	1	2
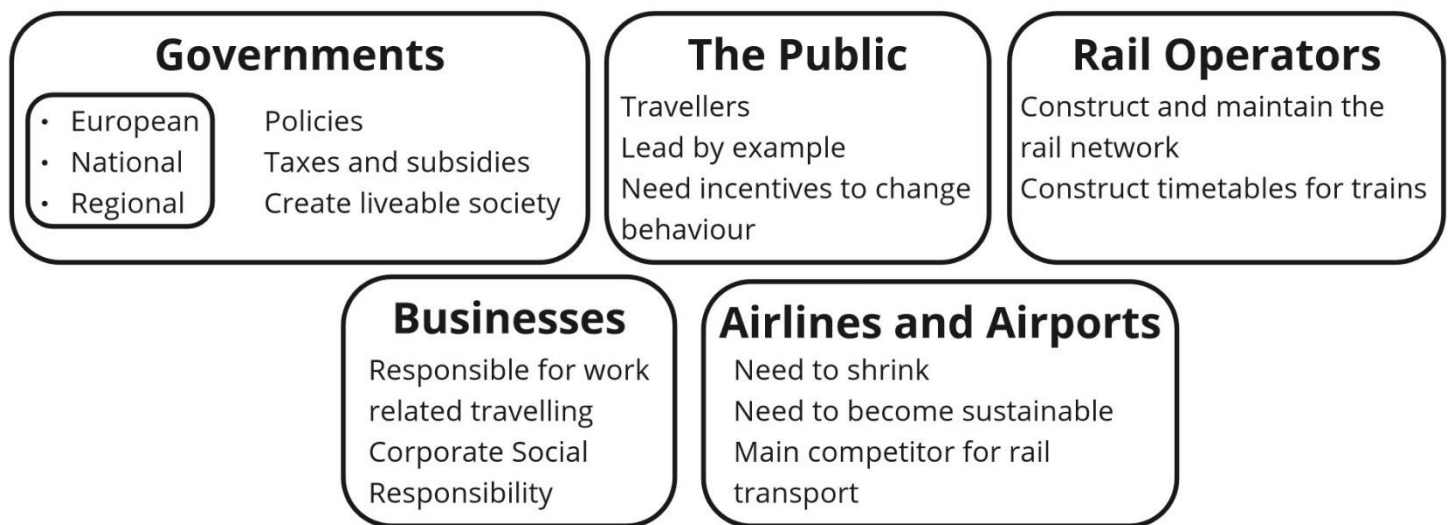
Figure 4.2: Overview of the main stakeholders and the main points of involvement.

Governments

It is possible to make a distinction between several levels regarding the overarching term for the stakeholder governments: European, national, and regional. All interviewees see "The government" as the most important stakeholder to establish a modal shift from air to rail and make train the main mode of transportation within the European Union for group travel. Especially European and national governments are seen as the most important stakeholders. Regional governments are also mentioned (interviews 3, 4), but to a lesser extent and with less power to change things drastically.

According to the interviews (interviews 2, 5, 6, 8), two of the main tasks of governments are the need to create a liveable environment as well as establish good infrastructure in the region where a government operates. Both of these tasks are part of reaching climate neutral transportation. Governments can develop policies, levy taxes, and grant subsidies to incentivise people to choose a more sustainable mode of transportation, for instance the train. Governments can also demand certain quality standards for rail operators to meet, in exchange for subsidies. Strong leadership is needed from governments in working towards climate neutral transportation.

The public / the users

The public is seen as the general people, the stakeholder that travels, or the users of the transportation modes. They decide which modality they take to reach their destination, which destination they choose, and whether they travel at all. The public shows certain travel behaviour in which they make choices about how, when, and where to travel. These choices are based on generalised transport costs including money, travel time and factors like comfort, safety and ease. To establish a modal shift, the public needs to be incentivised to change their travel behaviour and to choose for the sustainable transport mode. The public will not act on their own responsibility most of the time (interviews 1, 2, 5, 6, 7, 8, 9). As long as they consider the sustainable option not to be beneficial, mainly on the short-term, they will not choose for this option. Some people will act in a

responsible way and can lead by example, bring sustainability to the attention of the companies they work for and point out that there is a corporate social responsibility (interviews 3, 6, 9).

Rail operators

Rail operators are the stakeholders controlling the rail infrastructure and taking care of the rail system. They ensure that construction and maintenance of the rail infrastructure takes place, that trains run on time and construct the timetable for it. These rail operators are mostly nationally organised, often even (partly) state owned. The rail operators earn money from running train services and can receive subsidies from governments for the construction and maintenance of the rail systems.

Businesses/companies

Within this stakeholder group, businesses and companies in general are represented. It is a very broad term for describing this stakeholder, but each company has a similar influence in reaching the vision. All these businesses employ people, who need to travel to their work or have work related meetings. Businesses have influence on the travel behaviour of their employees, whether to travel or not and which mode of transport they use to reach their destination. An initiative from businesses that is mentioned by interviewees is the Anders Reizen Coalitie in the Netherlands (interviews 6, 8). This is a large group of businesses that motivate their employees to travel in the most sustainable way for their work-related travels.

Airlines and airports

Within this modal shift, or the transition towards a climate neutral transport sector in general, the aviation sector definitely has a role to play. When less people will travel by airplane, the consequences will be felt by airports and airlines. Will airports and airlines focus on making money, or do they take responsibility and actively help to make aviation emit less GHGs? When working towards climate neutral transportation, aviation needs to make a choice either to become a sustainable mode of transportation or decrease the number of flights.

Other stakeholders

Besides these main stakeholders, the interviewees mentioned, although less often, several other stakeholders. These stakeholders can definitely play their part and contribute to or complicate a modal shift towards the train in different ways. Stakeholders like the aviation lobby, tour operators, destinations, and overarching sector representatives can all help by promoting sustainability within their own sector and to the public. Tour operators and destinations need to anticipate the influence of a modal shift and change in travel behaviour with regard to other modalities and a change of destinations. They have to be prepared and make it part of their business.

Another stakeholder are the manufacturers of components for rail infrastructure. To accomplish uniformity of the rail systems within the European Union and to create a more sustainable construction of rails, the manufacturers will have to make changes in their production processes.

Academia can help with all kinds of research regarding the best ways of implementing new rail, developing sustainable aviation techniques, research on travel behaviour and identifying the barriers people meet in order to change their behaviour. Behavioural experts can play a role in this as well to advice companies and governments on how to lower these barriers in a constructive way and incentivise people to choose the sustainable alternative.

4.3.3 HOW can these changes be achieved?

After the findings on the WHAT and WHO questions discussed in the previous chapters, now the findings on the HOW question will be discussed. In the HOW section the question will be answered how the changes discussed in the WHAT chapter can be reached. This HOW question is answered by the findings from the interviews.

The findings for the HOW question will be presented in three topics: Interventions for the 1) train, 2) aviation and 3) behavioural change. For each topic a table will be shown in which the interventions and changes that are needed (WHAT) are coupled to the stakeholders that are involved (WHO), and how these interventions and changes can be achieved by specific actions (HOW). In the following sections the data from these tables will be discussed in more detail.

Train

On the train side of things, certain interventions on several aspects can increase the use of train. All the interventions are aimed at making the train a more attractive alternative transportation mode, mainly to substitute the airplane, but also the car. Interventions and changes that could be implemented for the train are shown in Table 4.6. In this table, the HOW is not yet coupled to the stakeholder (WHO).

Table 4.6: List of interventions for the train coupled to stakeholders.

What	Who	How	Interview
Use existing rail more efficiently	Governments	Create cooperation between national rail operators with regard to international train routes	2,3,4,6,7,8
	Rail operators	Formulate quality requirements by the government for train services in exchange for subsidies for rail operators	2,3,4,6,7
		Digitalise the rail safety systems	6,7,8
		Introduce night trains	2,4,8,9
Construct more rail lines	Governments	Uniform rail systems throughout Europe	1,7
	Rail operators	Investment in new rail infrastructure	3,4,6,7,8,9
	Manufacturers	Introduce sustainable manufacturing of rail components	1,4,5,7,8
	Academia	Research useful new rail lines	3,4,6,8
		Make working on rail infrastructure more attractive	1,7
Booking train tickets becoming easier	Rail operators	Share data about train timetables have to be shared	4,6
	Third parties	Introduce online ticket platforms for international train tickets have to be introduced	1,3,4,6,7
	Governments		
Less travel time for train	Rail operators	Provide less stops at small stations	4,8
		Set up efficient timetable to minimise transfer time	1,4,7,9
		Uniform rail systems throughout Europe	1,7
Implementation of ERTMS	Governments	Educate people to have the skills to implement ERTMS	1,7
	Rail operators		
Cheaper train tickets	Rail operators	Provide subsidies on train tickets and for construction and maintenance of rail infrastructure	1,6,7,8,9
	Governments	Lower taxes on train tickets	1,6,7,8,9
		Allow competition on the rail network	8
Better door-to-door travel time for trains	Regional governments	Provide transfers from station to residence	3,4
	Destinations	Provide the availability of shared mobility at train stations	3,4,5,6,7,8
	Tour operators	Locate key locations and services near the station	1
	Residences		
Electrify trains in Europe	Governments	Investment in electrifying rail	1,3,4,8
	Rail operators	Produce electricity sustainably	3,4
	Power providers		

The intervention mentioned most, is the use of the existing rail network in a more efficient way. This is an intervention that will take less time than the construction of new railway and it is therefore a very powerful resource to increase the capacity of the rail network. To improve the efficiency of the existing rail network, governments and rail operators play an important role. First of all, from the interviews it became clear that the collaboration between different national rail operators does not exist or proceeds with difficulty (interviews 2, 4, 6, 7). Their conflicts form a barrier that needs to be overcome. In this, governments can play an important role, especially with support of the institutions

of the European Union. If the train has to become the main mode of transportation throughout the countries of the EU, the institutions of the EU can link the requirement of quality standards for the national rail operators to subsidies for the maintenance and construction of rail (interviews 2, 3, 4, 6, 7). Within these quality standards, requirements for the collaboration between the rail operators have to be present, as well as the demand for uniformity of the rail systems throughout Europe. This uniformity should make passing the border during an international train trip easier and also more routes can be offered because of a better collaboration between the rail operators.

A task of the government is also to invest in good infrastructure. The construction and maintenance of the rail network should be (partly) financed by national governments and in a European context (interviews 6, 7, 9). To achieve an improvement of the rail network in the best way, research needs to point out which routes new rail lines will achieve the most positive effects on the quality of the train service (interviews 3, 4, 6, 8). Besides the construction of new rail lines, the digitalisation of the rail security systems will increase the efficiency of the existing rail network (interviews 6, 7, 8). The European Union is already working on the implementation of the European Rail Traffic Management System (ERTMS). This system will accomplish a transition from an analogue to a digital safety system for rails, as a result of which the train is safer, more reliable and efficient. All these aspects can help to increase the attractiveness of the train as a mode of transportation, as the capacity of the rail network can increase, travel times can become shorter and travelling by train becomes safer. The implementation of ERTMS will also help in working towards a uniform rail network throughout the EU. With the implementation of ERTMS, trains can drive faster, closer to each other and timetables will become more efficient. This implementation process should be sped up by stronger and more powerful leadership on a European level. A barrier for a faster implementation of ERTMS, but also for the construction and maintenance of rail infrastructure, is the lack of skilled people, who are prepared to work on the rail infrastructure. Working on rail infrastructure often happens at night, or on other less preferable times compared to other construction work, which makes the work less attractive. Also, the high quality and safety demands for people working on the rail infrastructure makes it harder to find sufficient people for these jobs. These jobs should be promoted, or incentivised and certain quality demands could be reviewed to make it easier to recruit people and to perform the work (interview 1, 7).

Another requirement to be dealt with on a European level, should be to demand from the national rail operators to share their data of the timetables with third parties. This will simplify the booking of tickets for passengers, as they will have a better access to important information about their international trips. Overarching companies, as already exist in the aviation sector where tickets can be easily compared and found, can be introduced in the train sector when data will be available (interviews 1, 3, 4, 6, 7). Also claims from passengers about delays, or trains that are missed by passengers due to delays have to be handled with a better customer service. An overarching organisation could handle these claims to prevent people to have to address several institutions for compensation for their bad travel experience (interview 4, 6).

To improve the travel experience by train, the timetables should be planned in such a way that trains will arrive all on the same time at an important node station to enable passengers to transfer to another train. When all these trains arrive on the same time with sufficient time for passengers to transfer between trains, the time spent waiting during a transfer can be minimalised. This improves the travel experience for passengers, as time spent in a vehicle is perceived less negative than the time waiting during a transfer (interview 4). In the timetable, stops on long international train routes have to be minimalised. When a train has to stop at every small station it passes, the travel time increases drastically. To limit the number of stops, local communities, together with rail operators

and national governments have to decide which stations are important for an international train to stop in order to decrease the number of stops on less important stations. This could also be a quality requirement from the European government to forbid rail operators on long international trains to stop at too many stations (interview 4, 8).

The introduction of night trains can increase the capacity of the existing rail and make the travel experience more enjoyable. For long distances travelling by night while asleep is a very efficient way of travelling, and this can increase the competitiveness between the train and airplanes (interviews 2, 4, 8, 9). Another focus point to improve the travel experience is the improvement of transfers from stations to the final destination. The availability of shared mobility, taxis or shuttle services from and to hotels or resorts at train stations facilitates the reaching of the destination. Most of the time, these services are present at airports, but this should be expanded to train stations in order to make travelling by train and reaching the final destination more comfortable (interviews 3, 4). Tour operators and hotel owners for instance could offer shuttle services to their clients and guests for the transfer between train station and their place of stay (interview 4). Regional governments or the destinations themselves can take care of a good system of shared mobility, car rental, taxis, etc. being available at the train stations. Also key locations, like offices or attractions being in the vicinity of a train station, is an aspect local government can look into (interview 3). Plans for the development of new offices or attractions could involve a train station being in the vicinity.

A much-heard argument for not using the train is the fact that travelling by train is often the most expensive transport option. It is challenging to make traveling by train cheaper, as the construction and maintenance of the rail infrastructure is very expensive (interviews 5, 8). Competition between rail operators could decrease prices as can be seen in other sectors where market forces are at place (interview 8). Subsidies from governments towards the train sector can also help in decreasing the price of train tickets. Taxes on train tickets and on the energy used by the trains can be lowered to reduce the price as well (interviews 1, 6, 7, 8, 9).

To work towards climate neutral transportation, two main steps can be taken to make the train more sustainable. The train is already seen as a sustainable mode of transportation, mainly because trains use electricity, and this electricity can be produced in sustainable ways. Not all trains within the EU run on electricity, however. This is another aspect to be organized on a European level, to invest in electrifying rail which is not yet electrified. To make the train more sustainable, this electricity has to be produced in a sustainable way, which also needs investments on a European level and from national governments (interviews 3, 4).

Aviation

An overview of the interventions for the aviation side are shown in Table 4.7.

Table 4.7: Interventions for aviation coupled to stakeholders.

What	Who	How	*Interview*
Make aviation more expensive	Governments	Increase taxes on aviation fuels	2,3,8
	Airports	Increase taxes on plane tickets	3,8
	Airlines	Prohibit flights to create scarcity	2,3,8
Make aviation climate neutral	Governments	Invest in clean aviation technologies	3,4,5,6,8
	Academia	Prohibit unsustainable aircrafts to fly	2,3,8
	Aircraft manufacturers	Cooperation with the aviation lobby to work towards sustainability	3
	Aviation lobby		

The important reasons for people to prefer the plane to the train for travelling are the costs, the time spent travelling, and the ease of the booking process. Aviation has an enormous advantage of not having to construct infrastructure in the air for an airplane to move, which makes airplanes very cost-efficient vehicles (interviews 4, 5, 8). Furthermore, at this point in time, airlines pay no or very little tax for the aviation fuels. This tax advantage was implemented by the Chicago convention and complicates the introduction of taxing on aviation fuels (interviews 3, 7, 8). Therefore, it is possible for airlines to offer very cheap tickets to the public. To make a modal shift happen from air to rail, aviation has to become more expensive.

Making aviation more expensive could be helpful in the sustainable transition. On the one hand it will lead to less attractiveness of aviation and at the same time the money earned by making aviation more expensive could be spend on investing in sustainable transportation modes like the train (interview 1). The European Commission is formulating and implementing an emission trading system in which polluters have to pay for their own emissions of GHGs. This system helps to reach a fair distribution between the emissions and the costs. Companies with high emissions of GHGs have to pay more than companies that emit less GHGs (interviews 5, 8). In this way sustainability is rewarded, which stimulates companies to reduce their pollution as it becomes expensive. Since aviation is polluting, this system can lead to an increase of the price of plane tickets, and it could be an incentive for the aviation sector to speed up their sustainability program. In the long-term climate neutral airplanes would be a very efficient way of transportation, as less infrastructure is needed compared to the train (interviews 3, 4, 5, 6, 8). But in the short-term, using more electrified trains will help in moving towards climate neutrality within the transport sector (interviews 4, 8). Still, investments in making aviation climate neutral are needed to speed up this transition towards climate neutral transportation.

Besides the emissions trading system there are other means to increase the price of flying. Also taxes on aviation fuels, taxes on plane tickets and creating scarcity by decreasing the number of flights permitted from airports can lead to an increase of the price of plane tickets. These are all instruments for governments to work on, as the aviation sector will not take the responsibility to fly less or increase their ticket price on its own initiative (interviews 1, 2, 8, 9).

There could be an important role for the aviation lobby if they are willing to change the agenda from blocking and hindering attempts to reduce aviation travelling to promoting sustainability within their sector. They could cooperate and step in with all the plans to make aviation sustainable (interview 3).

Behavioural and cultural change

Table 4.8: Interventions for behavioural and cultural change coupled to stakeholders.

What	Who	How	Interviews
Travel less	Businesses	Promote working at home	3,5,8
	Governments	Attend meetings online	3,5,8
Choose destinations closer to home	Marketeers	Promote destinations that are reachable by train	4
	Tour operators	Prohibit advertisements for flying vacations	1,8
	Businesses		
	Regional governments/Destinations		
Choose the sustainable alternative	Businesses	Make the sustainable alternative attractive	1,3,6,8
	Governments	Promote the train among employees	6,8

In Table 4.8 the interventions that focus on behavioural and cultural change are shown and will be discussed in the following section. For the transport sector to become climate neutral a change in travel behaviour is needed. Travellers need to choose the sustainable transportation option instead of the more polluting ones. This change in travel behaviour has to be incentivised, as people on their own will not act on responsibility (interviews 1, 2, 5, 6, 7, 8, 9). Without incentives to change the travel behaviour of people, a modal shift from airplane to train will not happen fast enough.

As long as the train cannot compete with aviation in terms of ticket prices, speed, ease of booking and comfort while travelling, the public prefer the airplane for their travels. This became clear from all interviews as it was mentioned in some form by all the interviewees. It is essential to first overcome these barriers. Several interventions as levelling the prices, increasing capacity on the rail, and less travel time for the train, are already discussed to make the train more attractive compared with the airplane.

Some barriers are clear and have already been discussed. Among these barriers are the generalised travel costs. Further barriers could be identified by behavioural experts. Identifying the barriers helps to formulate the right interventions to enable people to change their behaviour. Besides making the train more attractive, the focus could also be on changing travel behaviour. The choice of destinations can be changed in a way that taking the train becomes more attractive. Closer to home destinations can be reached by train and airplane. When it is possible to shift the focus more on destinations that can be reached by train easily and cheap instead of destinations that can only be

reached by plane, a shift in travel behaviour could occur (interviews 3, 4, 8). In order to achieve this change in behaviour, tour operators and marketeers can play an important role by looking into these possibilities and advising their clients to shift their focus on these destinations. It is likely to presume that they need incentives to make this shift. The government could provide these incentives, for example, by prohibiting the advertisements of flying vacations (interview 1).

Businesses could also play a role in encouraging their employees to travel less and take the train instead of the airplane. They can do this from the perspective of corporate social responsibility. By encouraging people to work from home and attend meetings online (interviews 3, 5, 8). They can also incentivise employees with regard to the means of travelling in case of a vacation, by stimulating travelling by train with an extra day off (interview 3).

4.3.4 Concluding the results from the interviews

To conclude this results chapter, in a short overview the main findings from the interviews will be given in order to explain on which the pathways towards making the train the main mode for passenger transportation within the EU are based.

From the interviews it became clear that the transition to climate neutral transportation within the EU does not rely on a complete shift towards travelling by train. The train can still play an important role in the transition towards a climate neutral transport network. Trains running on sustainably produced electricity already are more sustainable than fossil fuel powered transportation modes.

To enable a shift from aviation towards the train, from a sustainability perspective, it is better to increase the capacity on the current existing rail network, instead of constructing new rail lines. Other important aspects in this respect are the improvement of the soft factors as comfort while travelling and the ease of booking. To make the train more attractive for travellers, train tickets need to become cheaper, and competing modalities like the airplane need to become more expensive. Travel costs are one of the main considerations for travellers when they choose how to travel. Furthermore the travel time has to be reduced for the train. This can be achieved by implemen. ERTMS and constructing an efficient timetable for trains.

The main goal should be becoming climate neutral, which not necessarily means a complete shift of transportation towards rail transportation. This implies that the construction of new rail lines is less desirable, since the construction of new lines has a huge impact regarding the emission of GHGs. Besides the considerations with regard to sustainability, the investment costs are high. Sustainable aviation is seen as a good alternative for the future. For flying no infrastructure has to be used in the air which makes aviation an efficient transport mode. The downside is that the implementation of sustainable aviation is a very long-term project.

The public, or travellers, are the stakeholders that use the transportation modes, and they are the ones that make choices of travelling modes. They need incentives to change their travel behaviour in order to have them prefer the train to the plane. Incentives are also needed for the public to choose the sustainable alternative in general, with regard to destination choice, and travel frequency.

The governments, on a European and a national level, can play an important role in providing these incentives. They can levy taxes to increase the price for plane tickets, limit the number of flights permitted on airports, and they can also make the train more attractive. Lowering taxes on energy used by trains, and granting subsidies on train tickets make the train cheaper. Also setting some

quality requirements for the rail operators to increase the capacity of the rail network and improving the travel experience can make the train a more attractive transportation mode for the public to choose. Another requirement can be the encouragement of the cooperation between national rail operators to introduce good international train routes.

From the abovementioned insights about the transition towards climate neutral transportation with the focus on shifting from passenger aviation to rail transportation, pathways can be formulated to reach these goals and the vision formulated in chapter 4.2.

5. Pathways

The aim of this research is to formulate pathways towards the vision of making the train the main mode of transportation for group travelling within the European union and to be a climate neutral way of transportation in 2050. The interviews with experts that were conducted have produced a list of actions and interventions and give answers on what should be done and how it can be done. In the interviews also the stakeholders involved and the roles they play have been identified. The pathways that are formulated are based on these findings, as well as on findings from literature. The researcher has made the choices about which actions to take and in what term, based on his own interpretation of how it should be done. This interpretation and perspective on the issue have been formed on basis of the findings from the interviews combined with the background information from literature. And finally, the outcome is also based on his own critical perspective and analysis of the problem. The choices made in the following chapter will be explained as clear as possible and explain the why of an intervention and why it should be done in a certain term.

One of the main findings from the interviews about making the train the main mode of transportation for group travel was that it is very hard to accomplish this achievement in the given timeframe and that this goal might not be desirable for reaching the larger goal of reaching climate neutrality. Although electrified trains can be climate neutral when they run on sustainably produced electricity, various barriers and negative impacts of the construction and maintenance of rail infrastructure (Table 4.2), lead to the conclusion that making the train the main mode of transportation is a less desirable vision. Apart from that, the inability of the train to reach certain destinations sustains the need to use the airplane for transportation and certain journeys cannot be substituted by train completely.

Another interesting finding from the interviews is the priority of discouraging aviation first to then increase the use of the train. To increase the use of the train, the competing transportation mode has to become less attractive in the first place. Aviation is a very efficient, fast, and cheap mode of transportation, which makes travelling by plane an attractive option. Interventions that only target the train, and making the train more attractive are not enough to make the train the main mode of transportation. Aviation needs to be discouraged.

Although the outcome of the research leads to the conclusion that a complete shift of transportation to the train is not very desirable, now in a short description will be discussed how the vision in which the train becomes the main mode for group travelling in Europe can be reached. Several of the interventions that are used to reach this vision can serve as a starting point for creating the basis to reach a more desirable future vision. The choices made for interventions and the terms in which they are implemented will not be discussed in detail, as this will be done for the interventions in the pathway towards the adapted vision in chapter 5.2.

As a result of the findings in the interviews, the vision has been adapted to be more focussed on sustainability and the transport sector becoming climate neutral in general. The intervention pathway towards this adapted vision will be discussed in chapter 5.2.

5.1 Making the train the main mode

To reach the vision of making the train the main mode of group travelling, interventions can be focussed on two aspects: increasing the number of passengers in the train and decreasing the number of passengers in other modalities. The several aspects of doing this will be discussed in the next section which is divided in interventions focussed on the train, and interventions focussed on other modalities, mainly the airplane. The goal of these interventions is to make the train the main mode of transportation for group travelling within the European Union. The two pathways will be put together to work towards that vision.

Interventions focussed on aviation

The interventions focussed on aviation have two goals, being 1) decrease in number of flights, 2) discouragement of passengers to choose the airplane. Passengers who cannot or prefer not to take the airplane as means for travelling, will look for alternatives. A pathway of interventions for discouraging aviation is shown in Figure 5.2. The goal of these interventions is to help reach the vision of making the train the main mode of transportation for group travelling in the EU. The interventions will be discussed in short in the following section.

Short Term
- Stop subsidies on fossil fuel
- Increase taxes on aviation fuel and plane tickets
- Decrease the number of flights permitted at airports

Medium Term
- Prohibit advertisements for flying vacations
- prohibit flights between destinations with a competitive rail connection

Long Term
- Prohibit unsustainable flights within the EU
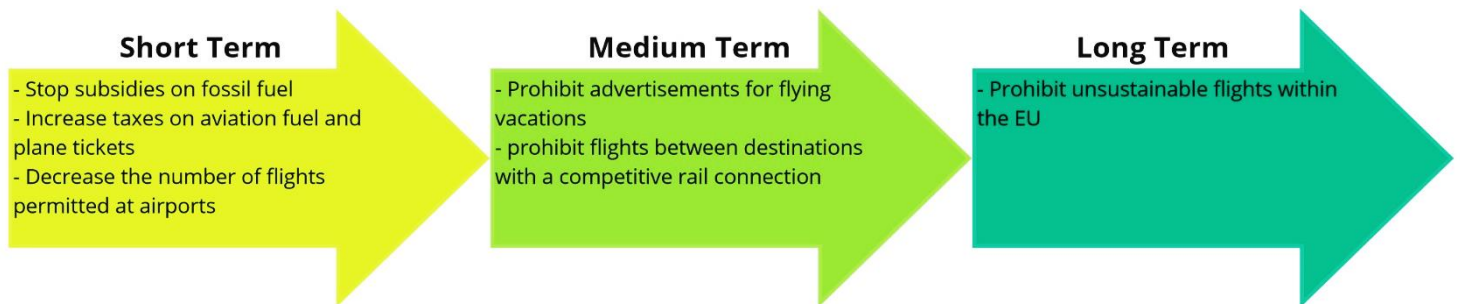
Figure 5.2: Pathway of interventions focussed on aviation.

The main focus of the interventions is to increase the price of plane tickets and at the same time decrease the number of flights available. By increasing the price, passengers will look at cheaper alternatives to travel. Aviation is a very efficient transportation mode, as no infrastructure is needed in the air. Besides this, no or almost no taxes are levied on aviation fuels and plane tickets. This is the reason that plane tickets are very cheap compared to other transport modes, which makes aviation a very attractive choice for passenger for their travels.

Short-term interventions that should be implemented with immediate effect are the stopping of subsidies on fossil fuels and increasing the taxes on aviation fuels and plane tickets. Governments should not be allowed to invest in practices that are very harmful for the environment. The intervention of decreasing the number of flights permitted at airports is a first step towards less aviation. Over time the number of flights permitted should decrease more and more. The flights can be prohibited based on the availability of competitive alternatives and whether or not flights use more sustainable techniques.

The prohibition of advertisements of flying vacations could be an intervention for the short-term. A prohibition, however, is a more drastic intervention which can encounter resistance from the aviation sector which could delay the prohibition. Prohibiting these advertisements, on the other

hand, can be a successful strategy to diminish the awareness of passengers of the possibility to fly and it could lead to travellers choosing an alternative.

Interventions focussed on the train

The main priority is to discourage flying, but besides this, interventions to encourage travelling by train need to be implemented. These interventions should focus on the improvement of the attractiveness of travelling by train, as well as an increase in capacity on the rail network. This will lead to an increase of passengers travelling by train. Most interventions will have to be initiated by governments. They have a responsibility to create good infrastructure and a liveable world, and they have a minor commercial focus (interviews 2, 5, 8). Businesses and transport companies have a more commercial focus, and their goal will be to maximise profits most of the time. This could be a reason they act less on sustainability on their own at the moment it does not increase their profit. Therefore, governments have to show strong leadership, with powerful policies. In Figure 5.1 the

Short Term
- Better timetable
- Less stops on international routes
- Introduce more international routes on existing rail
- Run more trains on existing rail
- Promote more destinations reachable by train
- Research usefull new rail to construct
- Establish an overarching ticket platform

Medium Term
- Implement ERTMS on important train routes
- Construct new rail on important routes
- Lower taxes or grant subsidies for train tickets

Long Term
- Implement HSR between every important destination
- Implement ERTMS on the whole rail network

Figure 5.1: Pathway of interventions focussed on the train.

interventions are shown for the short, medium, and long-term.

Two important interventions to increase the capacity of the rail are the implementation of ERTMS and the construction of more rail and HSR connections between important destinations. ERTMS allows safer and more efficient use of the rail network combined with an extension of rails, more people can make use of the train. Both interventions, however, are for the long-term, as it takes a long time to realise. A good compromise is to start implementing ERTMS and to realise construction of new rail lines on routes that are the most useful. Routes that are used often benefit the most with an increase of the capacity in trains and on rail. It is advisable to do further research on these possibilities.

Another intervention that could work, as long as new rail lines are not constructed yet, is to increase the capacity on rail by optimising the timetables of the trains. It is advised to do this in a way that more trains can be accommodated on the existing rail, combined with a minimalization of the time during transfers and the introduction of more international routes with fewer stops.

Besides interventions to increase the capacity, it is also essential to work on interventions to make the train more attractive for more passengers. Financial incentives by lowering the prices of train

tickets are one of the main interventions, but to do this, investments need to be made. Optimising the timetable, which leads to more efficiency, makes the train more attractive for people as destinations will be reached within a shorter period of time. To make people aware of the possibilities of travelling by train, it is essential that the promotion of destinations that are reachable by train needs to be scaled up in order to level with the promotion to destinations that can be reached by airplanes. Furthermore, it will be helpful for passengers when they can book their tickets in an easy way by means of an overarching tickets system, which has to be set up.

The main stakeholders to initiate and establish adequate implementation of the interventions are the government and the rail operators. The governments, on a European, national and regional level, have to formulate quality requirements for rail operators to meet in return for investments and subsidies for the construction and maintenance of rail infrastructure. The optimisation of the timetable, the introduction of an overarching ticket system and the introduction of new international routes can all be included in these requirements. The choice which routes have to be constructed is also a task of the governments, because most rail operators are (partly) state owned. The execution and implementation of these interventions is mostly a task for the rail operators.

5.2 Towards a climate neutral group travelling

As became clear from the interviews, the vision of making the train the main mode of group travelling in the EU is not the most desirable future vision to work towards to when it comes to reaching climate neutrality. Because of this an adaptation of the initial vision needs to be made.

The adapted vision will be: *Group travelling within the EU will be climate neutral in 2050.*

The bigger goal for the European Union is to reach climate neutrality. The focus for this research is to make the transport sector climate neutral. It is not necessary that this will be realised by making the train the main mode of transportation for group travelling. A combination of a modal shift towards rail, investments into sustainable electricity, sustainable hydrogen production on a large scale, and sustainable airplanes is a more desirable way to look into, in order to move towards climate neutral transportation. Also, a change in travel behaviour has to be initiated, as less travel movements will attribute to a decrease of emissions caused by the transport sector. A pathway will be formulated towards a climate neutral transport sector, with the focus on group travelling. For the short-term, the modal shift from air to rail will still play an important role in this pathway to work towards less GHG emissions from the transport sector. On the long-term, aviation becoming climate neutral is another important part.

In Figure 5.3 a roadmap of the pathway towards a climate neutral transport sector is visualised. The interventions are grouped in four different categories: organisational, economic and structural, cultural and behavioural, and technical changes. This categorisation is based on the type of change the intervention will cause. Some interventions can be classified in multiple of these categories, but for the clarity of Figure 5.3 they are sorted in the category that suits best.

The interventions are furthermore subdivided in the terms in which they will be implemented. This can be the short, medium or long-term. This is based on the urgency and/or difficulty of the implementation.

The pathway towards a climate neutral transport sector will be divided into smaller pathways with different sub goals where interventions from the overarching pathway can lead towards. These smaller sub goals can be seen as a part of reaching the overall goal of a climate neutral transport. For the following goals a pathway has been formulated:

- Make the train more attractive
    - Increase the capacity of rail
    - Introduce incentives for passengers to choose for the train
- Make aviation climate neutral
- Establish change in travel behaviour

The overall vision is that this pathway contributes towards the vision that group travelling will be climate neutral within the EU in 2050. The main focus will be on group travelling, as this is the scope of this research. The main modalities discussed are the train and the airplane. The interventions discussed in the pathways are focussed on these two modalities. For realising this vision, the focus will be on the use of existing rail in a more efficient way, on accomplishment of a change in travel behaviour, and finally on investment in sustainable airplanes. The benefits of aviation seem huge compared to rail transport. Less infrastructure is needed, and travel speeds are much higher. Therefore, the focus on sustainable aviation needs to be taken into account. This, however, is only achievable in the far future. Therefore, for the short-term, the focus has to be on the train, as trains can run sustainably already. A behavioural change is needed to make passengers choose for the sustainable alternative on most occasions.

In the following sections the separate pathways towards the sub goals will be discussed. When combined, these pathways of interventions will lead to reaching climate neutral transportation for group travelling. Elements discussed in chapter 5.1 from the pathway towards making the train the main mode for group travel will be used for this pathway as well, but in a more nuanced and balanced way. The focus on sustainable aviation will also be a part of this elaboration whereas the ultimate goal no longer will solely focus on making the train the main mode.

Roadmap

Towards sustainable transportation within Europe

Organisational ▮ (cyan)
Economic and structural ▮ (red)
Cultural and behavioural ▮ (green)
Technical ▮ (grey)

Short Term → Medium Term → Long Term

Short Term

Cultural and behavioural
- Promote more destinations reachable by train
- Promote working from home and encourage meeting online
- Promote the train to reach your work

Economic and structural
- Lower taxes or grant subsidies for train tickets
- Stop subsidies on fossil fuels
- Increase taxes on aviation fuel and plane tickets
- Decrease the number of flights permitted at airports

Technical
- Research usefull new rail to construct
- Establish an overarching ticket booking system for international train tickets
- Invest in sustainable aviation techniques
- Educate people to have the skills to work on rail infrastructure

Organisational
- Introduce better timetables for trains
- Realise less stops on international routes
- Run longer trains on existing rail
- Introduce more international routes on existing rail
- Set quality requirements for rail operators
- Introduce more night trains
- Promote cooperation between rail operators
- Support sharing data about the train timetables

Medium Term

Cultural and behavioural
- Prohibit advertisements for flying vacations
- Prohibit flights between destinations with a competitive rail connection
- Cooperate with the aviation lobby to work towards sustainability

Economic and structural
- Locate new offices and key locations close to train stations

Technical
- Implement ERTMS on important train routes
- Construct new rail on important routes
- Establish good connected infrastructure from train stations to the final destination
- Establish uniform rail systems throughout Europe
- Make the manufacturing of rail components sustainable

Organisational
- Run more trains on existing rail

Long Term

Cultural and behavioural
- Prohibit unsustainable flights within Europe

Technical
- Implement HSR on the bussiest corridors
- Implement ERTMS on the whole rail network
- Realise a completely electrified European rail network
- Realise that trains run on completely sustainably produced electricity
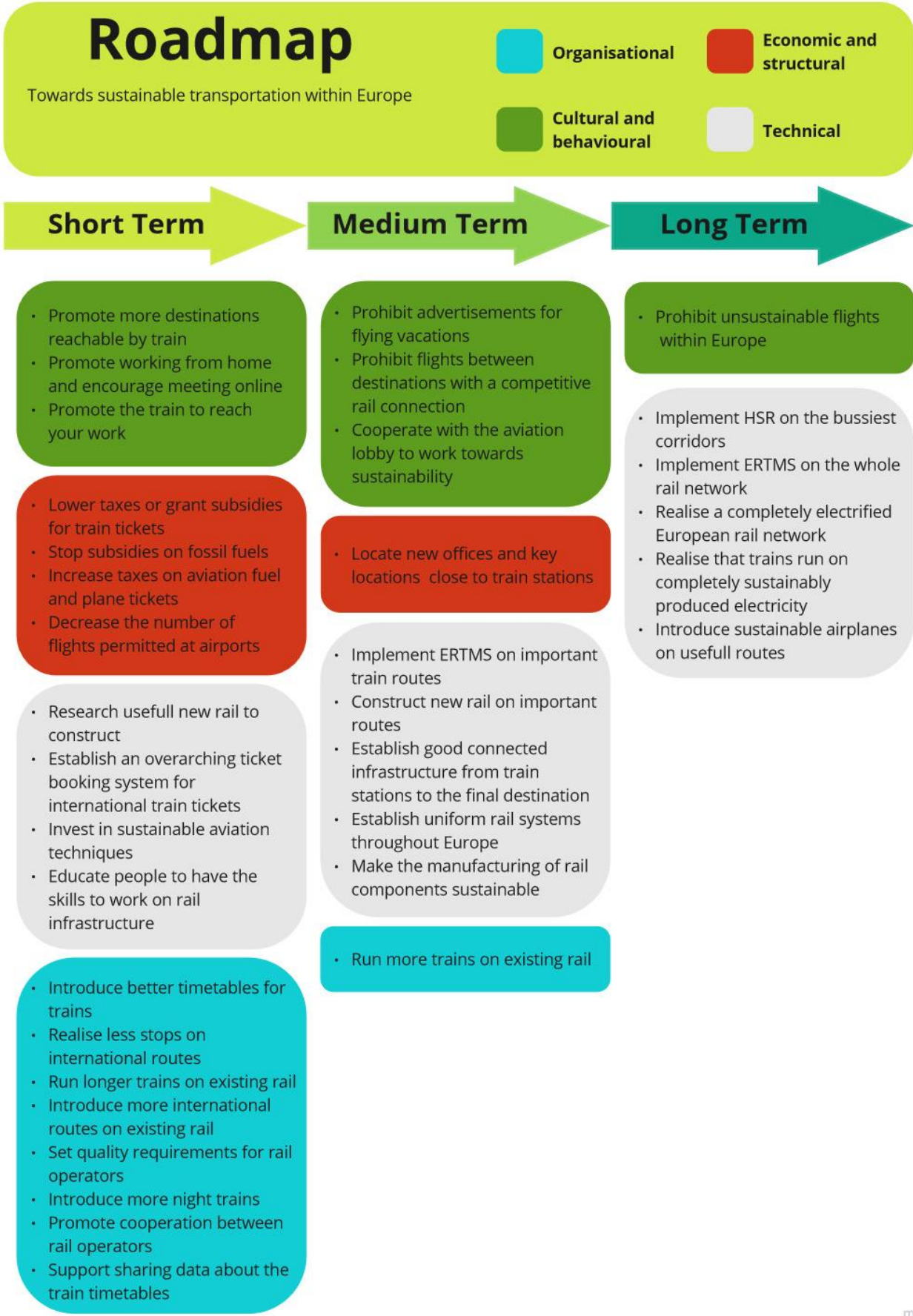- Introduce sustainable airplanes on usefull routes

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Figure 5.3: Roadmap of the intervention pathway towards climate neutral transportation within Europe.

5.2.1 Making aviation climate neutral

Aviation is an essential part of the transport sector. For longer distances, the airplane is the fastest option, and certain places are difficult to reach without the airplane, for instance islands. These examples make clear that sometimes it is difficult to replace the airplane. Aviation should be part of the transportation options. However, travelling by plane is not sustainable at this point in time because of the large amounts of fossil fuel used by airplanes. To combat climate change, while still be able to travel large distances, aviation has to become climate neutral. This, however, requires drastic measurements. Sustainable airplanes, running on electricity or hydrogen for instance, are innovations that will become operational in the long-term only, and large technical breakthroughs are needed.
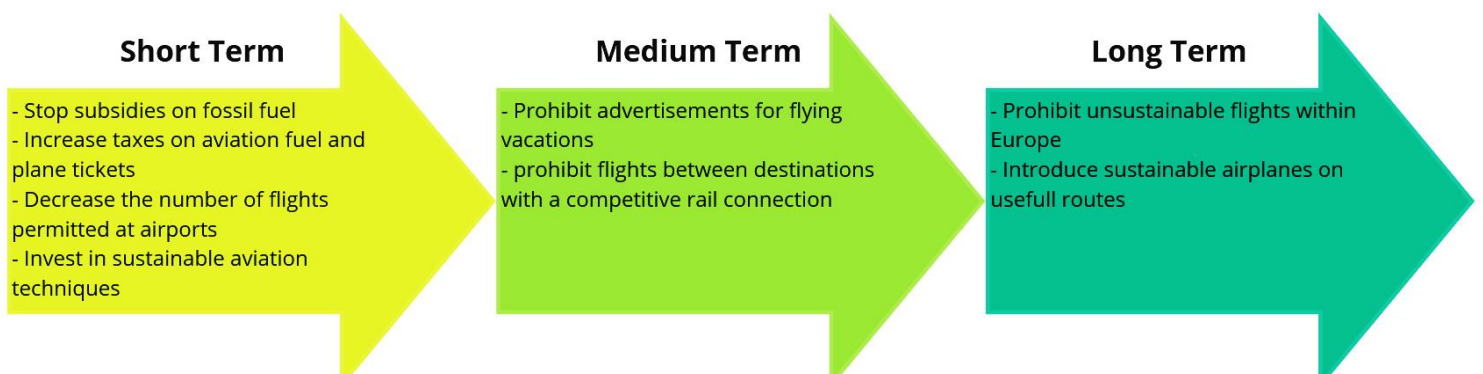
Short Term
- Stop subsidies on fossil fuel
- Increase taxes on aviation fuel and plane tickets
- Decrease the number of flights permitted at airports
- Invest in sustainable aviation techniques

Medium Term
- Prohibit advertisements for flying vacations
- prohibit flights between destinations with a competitive rail connection

Long Term
- Prohibit unsustainable flights within Europe
- Introduce sustainable airplanes on usefull routes

Figure 5.6: Pathway of interventions towards climate neutral aviation.

The two focus points for the pathway towards climate neutral aviation are *Reducing the current number of flights* and *Make aviation sustainable.* The interventions proposed for reaching these two focus points will also influence each other. The prohibition of unsustainable airplanes, for example, can accelerate the innovation towards sustainable airplanes as commercial interests are at stake. In Figure 5.6, the pathway of working towards climate neutral aviation is shown.

At this point in time, airplanes are not sustainable and are huge emitters of GHGs. This, combined with the huge number of passengers travelling by airplane make aviation a threat for the environment. Therefore, the number of flights have to be reduced to lower the emitted GHGs by airplanes in the short-term. To be more precise, the number of kilometres travelled by airplane has to decrease. If short flights are replaced by some longer flights, but the number of kilometres travelled stays the same, not much reduction in emitted GHGs will be established.

Reducing the number of flights can be realised by directly prohibiting flights, or by influencing passengers to choose for a sustainable alternative. Both these approaches will be elaborated in this pathway. Simultaneously, the path towards sustainable aviation will be followed. For the short-term it will be important to reduce emissions from aviation by reducing the number of flights. But in the long-term, aviation could become sustainable which is something that has to be encouraged and sped up.

Short-term

As aviation is very polluting at this point in time, the only realistic way of lowering emissions from aviation in the short-term is to fly less. In the short-term flying needs to be discouraged, and the main way to do this is to increase the price of travelling by airplane. Polluters will have to pay more for the pollution they cause, and therefore it seems fair to increase the prices of plane tickets.

Several actions can be undertaken to increase the price of plane tickets. First and foremost, governments need to stop to subsidise fossil fuel. One of the tasks of the government is to create a healthy liveable world, and subsidising polluting industries like the fossil fuel industry is in conflict with this task. By stopping these subsidies and investments, fossil fuels will become more expensive, which will have a negative impact on the profitability of aviation companies. This can lead to increased airplane ticket prices. These investments and subsidies for the fossil fuel industry could and should be stopped in the short-term. Politics play an important role in delaying or speeding up this process. Although, the lobby for the fossil fuel industry will put up barriers, stopping this financial support cannot stand further delay.

In line with this first intervention, taxes on aviation fuels and plane tickets need to be increased. This is in line with a polluter pays policy to discourage polluting practices. Levying taxes on aviation fuels and airplane tickets will increase the price of travelling by airplane. On a European level the emission trading system should be introduced and formulate this in a way that the polluter will pay. The European Union has implemented this emission trading system partly and they want to extent this policy. However, exceptions were made for the aviation sector and the sector was given some free GHG emitting space. In the future, this exception needs to be eliminated so that the aviation sector will have to pay for emitting GHGs. By introducing this policy, the price of flying will rise as well, and travelling by airplane will become less attractive.

Besides the policies to increase the price of flying, prohibiting certain flights, or restricting the number of flights allowed at airports, can also lead to an increase in price as a result. Governments should decrease the number of flights that are allowed to arrive and depart from an airport. Choices have to be made in how many long and short flights are allowed. When the number of flights will be restricted, airlines could change shorter flights for longer flights, as longer flights are more profitable. This would not lead to a decrease in emitted GHGs from the aviation sector, as longer flights emit more GHGs than shorter flights. Given the bigger goal of climate neutral transportation, this is undesirable and should be countered by clear policies on the permitted flights.

The implementation of taxes, policies, and restrictions could be done in the short-term. However, here as well, politics and lobbying can delay this implementation. The abovementioned incentives will lead to disadvantages for the aviation industry and their lobby will try to prevent these policies from happening.

Working towards climate neutral airplanes has to be started as soon as possible. This process is one for the very long time, therefore there is no time to waste. Governments and the private sector need to invest in the development of sustainable aviation techniques. Money gathered from the higher taxes on fossil fuels and the rise of plane tickets could be spend on these sustainable innovations. Furthermore, discouragement of polluting practices by means of the emission trading system in which the polluter pays makes it more attractive for the aviation sector to invest in and implement innovations towards sustainability.

Medium-term

In the medium-term, more drastic measures should be introduced for the aviation sector. The aviation sector will only become climate neutral on the very long-term, and in the medium-term airplanes will still emit GHGs while flying. Therefore, in the medium-term the amount of passenger kilometres travelled by airplane has to be reduced. Where in the short-term the focus was on

increasing the prices of plane tickets, in the medium-term there are more restrictions for the aviation sector to decrease the GHG emissions from aviation.

First of all, flights on routes with a competitive rail connection should be prohibited. When a competitive rail route is introduced, the number of flights can decrease drastically by decrease in demand alone. This is mainly the case on routes with a better travel time for the train, or similar compared with the airplane. Low-cost carriers offering flights on these routes can have a negative influence and lead to maintaining some flights on these routes (Dobruszkes, 2011). Therefore, the choice to prohibit flights on routes with competitive rail will establish this decrease in flights definitely. Prohibiting flights on these specific routes will lead to a promotion of the train to reach these destinations, which will be an immediate improvement towards climate neutrality of the transport sector. It is essential to point out that there is a risk that the freed-up time slots for flights at an airport can, at the same time, be filled up with longer flights without a competitive rail connection. When this happens, a reduction in flights will not lead necessarily to less GHG emissions as longer flights emit more GHGs. Therefore, a reduction in passenger kilometres travelled by airplane need to be established by restricting the number of flights permitted at airports, and not only a reduction in number of flights.

Not only certain flights should be prohibited, but also advertisements for flying vacations should be banned. Governments already have policies banning certain advertisements, for instance the promotion of smoking or gambling. This type of policy could also be introduced for flying vacations, or flights in general. Less attention for travelling by plane can lead to a diminishing of the awareness of people, in this particular case regarding transport by air. More promotion of travelling by train and less advertisements for planes could help with a shift from airplane towards the train.

The implementation of these interventions is for the medium-term, as for the substitution of flights with rail transportation, competitive rail connections have to be present. It needs some time for some of these rail connections to be established. Furthermore, it is likely that restricting the aviation sector will lead to opposition on their part.

Long-term

For the long-term, travelling in the EU should become climate neutral. Therefore, unsustainable transportation modes have to be banned. Unsustainable modes of transportation are modes that run on fossil fuel, or other energy sources that are harmful for the environment. Airplanes that run on fossil fuel emit large amounts of GHGs and should therefore be banned in the long-term. On the mainland of the EU, every destination can be reached without using an airplane, although it might take some more time. The prohibition of unsustainable airplanes is essential to reach climate neutral transportation. By prohibiting the flights with unsustainable airplanes, the pressure to innovate the aviation sector will increase and the introduction of sustainable aviation techniques can be sped up by this pressure. A parallel can be found in the automotive industry, where manufacturing more sustainable operating cars was pushed (European Parliament, 2019).

The introduction of sustainable airplanes is a long-term project, or even for the very long-term. It takes a long time to develop these techniques and it is even possible that these techniques will not be developed at all. Whenever these sustainable techniques become available, they have to be implemented in the transport sector, as aviation is a very efficient transportation mode.

5.2.2 Make the train more attractive

On the way towards climate neutral transportation, the train plays an important role, especially in the short-term. The train already is a transportation mode that emits less GHGs compared to airplanes. This is certainly the case with trains running on electricity where this electricity is produced by sustainable sources. Therefore, every passenger not taking the airplane, but travelling by train attributes to the progress towards climate neutral transportation. Therefore, one of the first focus points in the pathway towards a climate neutral transport sector will be to establish a modal shift from airplane to train.

To increase the number of people travelling by train, the travel experience by train has to be improved and become more attractive compared to other modalities (i.e., airplane). In order to achieve this goal, incentives for passengers need to be created. Furthermore, the capacity on the rail network has to be increased to accommodate more people that want to travel by train. The interventions that will be discussed for these two aspects of establishing a modal shift will complement each other, as both elements are needed for a fast realisation of this modal shift.

By improving the attractiveness of the train, more people will prefer travelling by train, and more capacity is needed. Simultaneously, creating more capacity on the rail and in the trains has a positive impact on the   attractiveness of the train and will lead to more people travelling by train.

Create incentives for passengers to choose for the train

Short Term

- Lower taxes on, or subsidise train tickets
- Set quality requirements for rail operators
- Establish an overarching ticket platform
- Promote more destinations reachable by train

Medium Term

- Locate new offices or key locations close to train stations
- Establish good connected infrastructure from train stations to the final destination

Long Term

- Create completely electrified European rail network
- Establish that trains are running completely on sustainably produced electricity

Figure 5.5: Pathway of interventions to improve attractiveness of the train.

Figure 5.5 shows the intervention pathway for the introduction of incentives for passengers to choose for the train. Creating these incentives is one of the most important things to establish in order to make passengers make the change away from unsustainable transportation modes towards sustainable ones. Creating these incentives helps making the train more attractive to choose as transportation mode. With lower prices, less travel time, and a better travel experience, travelling by train becomes more attractive and people will choose the train more often.

The interventions for this part of the pathway are closely related to the interventions for increasing the capacity on the rail. Some of the interventions discussed for increasing the capacity on the rail can be seen as interventions to make the train more attractive and create incentives for passengers.

Short-term

For the short-term, the most important intervention to make the train more attractive and to stimulate more people to choose for the train is to work on the price. It is essential that the price of train tickets is competitive with prices for airplane tickets. This can be done by lowering the taxes on the train tickets, but also by lowering the taxes on the energy that is used by the trains. Price of train tickets that are more appealing will lead to more passengers choosing for the train. This intervention needs to be initiated by the governments. The construction and maintenance of the rail infrastructure is expensive and is a part of the ticket prices for the train. Subsidies for construction and maintenance to the rail operators can lead to lower ticket prices. Also, a direct subsidy on train tickets can be introduced to incentivise people to take the train.

It is of course possible to formulate conditions to rail operators in exchange for receiving subsidies from the governments. The setting of requirements for rail operators in this regard can be seen as an overarching intervention which includes multiple action points. This should be done by governments, national or on a European level. In order to receive subsidies, rail operators should meet these requirements. The following requirements can be included to make the train a more attractive mode of transportation:

- National rail operators have to work together to establish international rail routes.
- Data has to be shared about the timetables to realise an overarching ticket platform.
- Less stops need to be implemented on long international routes for a better travel experience.
- A minimum of trains that need to run must be identified in order to keep the capacity high.
- The number of delays or cancelations of trains must be reduced to make the train a reliable transportation mode.
- Rail systems must be made uniform to improve passing the borders on international train routes.

These requirements have to be formulated and made mandatory for rail operators to meet. In this way, a certain quality standard for the train can be established and the travel experience for passengers will improve. The formulation and implementation of these requirements can be done on the short-term. It will also contribute to create certainty for rail operators in a way that they know about the focus points for the future. Not every requirement is necessarily required or even possible for the short-term. The uniformity of the rail systems throughout the EU, for example, can only be realised on a longer term.

At this point in time, national rail operators focus mostly on their own national rail network. Unfortunately, national rail operators are not working together and even on some occasions counteract each other. The cooperation between national rail operators is needed to create better international rail routes. When receiving European subsidies, cooperation between national rail operators is a requirement. When cooperation is established, new international routes might be easier to implement in the timetables.

The requirement of sharing data concerning the timetable is another important requirement. At this point in time, it is difficult to book train tickets for certain international routes, or routes that are not official. At the moment national rail operators share these data, third parties can create an overarching ticket platform comparable to ticket platforms that already exist for the aviation sector. With a better booking system, containing information about international trains, passengers can book train tickets more easily. Setting up a system comparable to the ones available for plane tickets should be possible in the short-term. Without the information, for international passengers it is very

difficult to book these tickets. The introduction of an overarching ticket system for all the trains that run in the EU increases the accessibility of the train, which will lead to more people travelling by train.

In order to get people to travel by train it is essential to draw attention to this mode of transportation. More attention to the train and the travel options to certain destinations, will lead to more awareness and it will help people to make the choice to go by train more. Promotion of the train, and the possible destinations that can easily be reached by train is an important requirement. Shifting the emphasis from cheap airplane tickets towards competitive train connections, creates awareness. However, it is hard to implement this intervention. The interviews only mentioned that the focus should shift towards travelling by train, but it was not mentioned how this shift could be realised. Travel agencies, or destinations will not voluntarily shift towards the promotion of the train, when less money can be made with train travels. Aviation is an attractive mode of transportation and therefor more people want to travel with the airplane. Therefore, more services can be sold for aviation. When travelling by train becomes more attractive, these tour operators could promote the train more, as more people might want to travel by train. A way to achieve more promotion for the train could be the prohibition of advertisements on flying vacations, or cheap plane tickets. This is an intervention that will be discussed in chapter 5.2.2.

Medium-term

Most of the time it is not possible to reach the final destination completely by train. Therefore, connecting infrastructure has to be put into place for the final kilometres to reach the final destination. This can be done in several forms. The availability of other public transportation modes, micro mobility, and taxis near the train station, will contribute to the accessibility of the train as a suitable transportation mode. This is a task for the regional government to realise. This intervention is something for the medium-term. Implementation of certain types of micro mobility, or creating a taxi stand near a station, does not necessarily take time, but choices need to be made what types of mobility local authorities prefer in their cities. The introduction of new public transport services near train stations will take more time.

An intervention which is in line with the one mentioned above, is locating key locations near train stations. In the future, regional governments, or newly starting companies should get the possibility, to locate their offices, or for instance amusement parcs or museums, near train stations. This way, travelling by train supports reaching the final destination in a much better way. This is an intervention for the medium-term as relocating offices or attractions closer to a train station needs time. Local authorities can make city plans for future key locations to be located near stations. From a corporate social responsibility perspective, businesses can also make the choice to locate new offices of the company near train stations. This enables companies to encourage their employees to travel by train to their work. Locating offices near train stations is an intervention that mainly will influence the travel behaviour on national routes as people will not internationally travel to their work on a daily basis. With regard to bigger touristic attractions visited by international tourists, the location near train stations, on the other hand, can influence international train travels when it becomes easier to reach that attraction by train.

Long-term

For the long-term interventions, the focus is on sustainability. The main goal for this pathway is to reach climate neutral transportation within the EU. For the train to become climate neutral, the trains have to run on sustainable power sources like sustainably produced electricity. A large part of the European rail network is already electrified. For the rails that are not yet electrified it will take a long time to realise complete electrification, since this has consequences for parts of the infrastructure. It can be challenging to electrify rail in places with no overhead lining yet, since there is a shortage of skilled people for the construction (interview 7).

For the electrification of the rail network within all the countries in the EU in order for the train to become climate neutral, all has to run on sustainably produced electricity. This can be produced by for instance solar and wind energy, but the clean electricity production needs to increase. For Europe to become climate neutral, the use of clean electricity is inevitable, therefore governments need to invest in clean energy sources. These are measures for the long-term, since the construction of all this energy infrastructure takes a long time. There is a broader debate about the choices of the sources to be used for the production of clean electricity which will not be discussed in this research. It is definitely something to be considered by policy makers. The discussions about the use of nuclear power, for instance, as an option, illustrate the difficulties around this topic.

When the train becomes more sustainable, in the future the price of train tickets can drop, as polluting practices most likely will be taxed more in the future. Taxing polluting practices is also one of the interventions in this pathway that will be discussed in chapter 5.2.2. Lower prices will attract all kinds of people and for people concerned about climate change, who for that reason already prefer the train, lower prices are a bonus.

Increase the capacity on rail

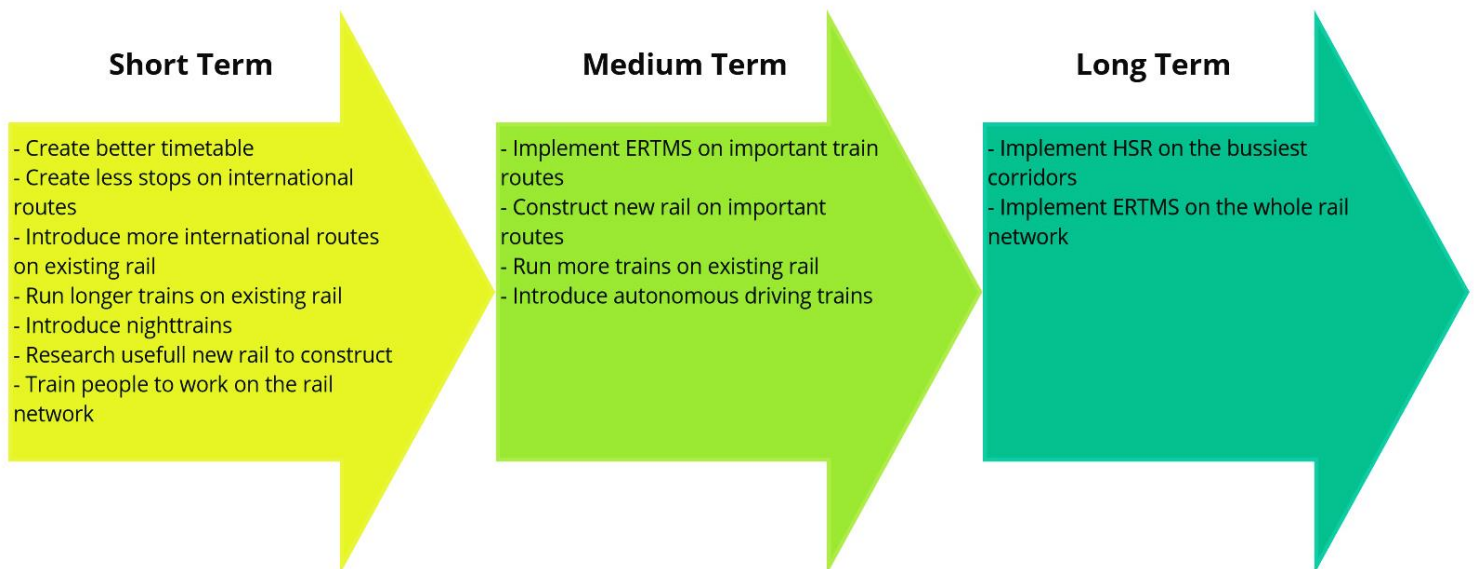| Short Term	Medium Term	Long Term
- Create better timetable - Create less stops on international routes - Introduce more international routes on existing rail - Run longer trains on existing rail - Introduce nighttrains - Research usefull new rail to construct - Train people to work on the rail network	- Implement ERTMS on important train routes - Construct new rail on important routes - Run more trains on existing rail - Introduce autonomous driving trains	- Implement HSR on the bussiest corridors - Implement ERTMS on the whole rail network

Figure 5.4: Pathway of interventions focussed on increasing the capacity on rail.

In Figure 5.4 the intervention pathway to increase the capacity on rail is shown. The interviews made clear that it is not desirable to construct more rail network because of barriers mentioned before (Table 4.2). The focus of this pathway therefore is to use the existing rail network as efficient as possible. Some new rail infrastructure might be needed, but this will only come into play on certain very busy routes. Using the existing railway as efficient as possible will create more capacity on the rail network in a shorter term than constructing new rail lines. Furthermore, investing in the construction of new rail lines can become sunken costs if in the future aviation becomes a climate neutral way of transportation. In the short-term however, climate neutral aviation will not be possible, and therefore the capacity on rail has to be increased.

Short-term

The main intervention for the short-term is the creation of the most efficient timetable for trains. As this is an organisational change, it will take less time than the construction of new rail lines for instance, while still increasing the capacity on the rail network. To construct this timetable, national rail operators need to work together. The focus and the priority during the creation of the timetables need to be on important, busy international train routes. These have priority in the planning of the timetable, followed by the shorter, national routes. At the moment, the focus of the national rail operators is on the national routes and barely on the international routes. This focus needs a little shift towards the international routes. When rail operators work together, new international routes can be introduced while using existing rail. When introducing these new routes, it is important to minimise the stops on those routes to keep the travel time competitive with flying on those same routes.

To create efficient timetables for the train, transfer times between trains need to be minimalised. This can be realised in two ways. The first one is to run as many as possible trains on routes to prevent long waiting time as trains can run every ten minutes. This is only possible on busy corridors with many travel movements. The second option can be useful for routes that are less busy and where trains cannot run every ten to fifteen minutes. For the second option, trains have to arrive at

the station around the same time and stay long enough for passengers to transfer from one train to another. This minimises the time spent during a transfer. Stations where many transfers take place, so-called node stations, qualify for the second intervention. With less time spent during transfers, both the travel time decreases, and the travel experience improves, which makes the train more attractive as well. Not only the introduction of more efficient timetables is a good incentive, but also longer trains on the existing rail can help to increase the capacity without using more trains. For longer trains it is a requirement, of course, that the length of platforms in the stations is long enough to accommodate these longer trains. The reality is that rail operators run shorter trains while longer trains certainly could have been used. Therefore, if possible, longer trains should be used to increase the capacity. This is a measure for the short-term and can therefore be helpful to quickly increase the capacity.

Furthermore, the introduction of night trains will increase the capacity on the rail network and might as well lead to more competitiveness of longer international routes. Travelling during the night while asleep is a very efficient way of travelling and can increase the competitiveness with the airplane also for longer distances. For the introduction, cooperation between national rail operators is needed, as well as good international rail routes being present in the timetable. The introduction of these night trains can be realised in short-term depending on the willingness of the rail operators to introduce these night trains.

As for some busy routes, the capacity on the rail is already used optimally and no extra capacity can be created without constructing new rail. Research has to be started to identify these routes where newly constructed rail can be of use. The construction of new rail lines costs time, and the investment costs are huge. Therefore, sufficient research is needed to investigate the choice of routes suitable for the construction of new rail lines in order to accomplish the largest increase in train travelling and decrease in aviation or car usage.

For the construction and maintenance of the rail network, as well as for the implementation of ERTMS, skilled people are needed. However, there isa shortage of these skilled people which will lead to delays. The delays in construction and maintenance on the rail network, and the implementation of ERTMS lead to less trains on the network, as well as delays and cancelations of trains, which has a negative impact on the attractiveness of travelling by train. To prevent these delays from happening, people need to be trained to acquire the skills to work on the rail infrastructure. Especially the implementation of ERTMS can increase the efficiency on the rail network, and therefore this implementation process has to be sped up. With more skilled people, the implementation should be finished quicker.

Medium-term

In the medium-term, the main intervention is the implementation of ERTMS. ERTMS is a digital safety system for the train network which will make the train network safer and more efficient. For the implementation of ERTMS many skilled people are required, and implementation will take a long time. Therefore, it is obvious to first focus on the routes with many trains and the transport of many people. Since more people are transported on these routes the implementation of ERTMS will have the biggest impact for the efficiency on the rail. The routes on which it should be implemented can be the routes identified by the research done in the short-term.

When ERTMS is implemented, it should be possible to work with a stricter timetable in order to have as many trains as possible on the rails and make optimal use of the existing rail network. This will

increase the capacity on the rail, and it will therefore be possible to accommodate more people to travel by train.

In the medium-term, also the construction of new rail lines will be started. These new rail lines are the ones that are identified by the research done in the short-term. Although it is not desirable to construct many new rail lines, the train is a safe bet when it comes to sustainable transportation. Already at this moment, rail transport can be a very sustainable mode of transportation, which cannot be said of aviation. Aviation becoming sustainable will take a long time, if it is even possible at all.

Long-term

The long-term of this pathway focusses on the implementation of ERTMS and the finishing of the construction of new rail lines. These are interventions that take a long time with regard to increasing the capacity on the rail and this column contains less interventions.

Nevertheless, the implementation of ERTMS is important, as already stated in the medium-term interventions. For the long-term, the rail network in all countries of the European Union should have ERTMS. For the implementation many skilled people are needed which makes this an intervention for the long-term.

Finally, the construction of the important new rail lines should be finished in the long-term. In order to make the proper choice it is essential to look at the distance between the destinations and whether these new lines should be an HSR line or not. For longer distances up to 1000 km, HSR will be a good alternative as a substitute for airplanes.

5.2.3   Enable change in travel behaviour

The core of the problem of the unsustainability of transportation is the travel behaviour of the passengers. The passengers make the choice to travel by airplane, train, car, or whatever kind of transportation mode. For the goal of making the transportation sector climate neutral, a change in travel behaviour has to be established which enables people to choose for the sustainable alternative. This can be a change in modality choice, destination choice, or even the choice not to travel at all. The major challenge is that people need incentives to change their behaviour. They will not alter their behaviour on their own. The choices people make are based on the generalised transportation costs as discussed earlier in the findings from the interviews. These generalised transportation costs should become more attractive for the sustainable alternatives and less attractive for the unsustainable options.

Interventions can be made for both lowering the barriers to choose the sustainable option and increasing the barriers to choose the unsustainable option. In this way the playing field can be levelled, or even switched in favour of the sustainable alternative. In the intervention pathways for making the train more attractive and making aviation climate neutral, several interventions are proposed that will lower or heighten barriers and will introduce incentives for people to choose the sustainable alternative.

To enable change in travel behaviour, no pathway will be formulated as the interventions will all be implemented on the short-term and should be still in use in the long-term.

In the pathway for making the train more attractive, which is described in chapter 5.2.1, the price of train tickets was lowered, the travel experience of rail transport improved, and booking tickets for international trains became easier. These measures lead to a lowering of the barriers to take the train. In chapter 5.2.2 prices of plane tickets were made higher, which raises a barrier to travel by plane. Besides these barriers, there could be other barriers as well that stop people from taking the train. It is advisable that behavioural experts to do research to identify all the barriers preventing people to take the train. Besides the barriers, different types of travellers should be identified. This is important in order to make policies and interventions to have the optimal influence on the travel behaviour of the specific group. Two groups identified by the interviews are business related travellers and recreational related travellers.

Governments can achieve a change in behaviour by implementing useful policies to encourage people to choose for the sustainable alternative. With the insights from the research concerning the barriers and the different types of travellers, policies can be made more effective to achieve sustainable travel behaviour. Levying or removing taxes on travel products, as well as prohibiting certain modes of transportation can be part of such policy packages. Governments can also promote destinations that are reachable by train. A change in destination choice among passengers can lead to a choice for more sustainable transportation modes. Interviewees mentioning this pointed out that destinations far away do not necessarily give a more enjoyable vacation. Therefore, the choice for journeys to destinations closer to home will also lead to a decrease in passenger kilometres travelled.

Businesses can help in enabling behavioural change as well. Acting on their corporate social responsibility, businesses can encourage their employees to work from home, attend meetings online and travel by a sustainable mode of transportation, for instance the train. This policy fits in a time where more people are aware of climate change. Employees themselves can also point out to their employers that there is a corporate social responsibility. Incentives regarding employees might be initialised by trade unions, for example.

5.2.4   Transition to sustainably produced energy

For transportation to become climate neutral, energy has to be produced sustainably. Electricity, hydrogen and biofuels can all be used as a sustainable energy source if they are produced in a climate neutral way. Most trains in Europe already run on electricity, and producing this electricity in a climate neutral way can make it possible to already run trains sustainable in the short-term. For potential sustainable airplanes, electricity could also be used, but hydrogen or biofuels could be more suitable options for aviation. For the aviation to become sustainable, hydrogen and biofuels have to be produced sustainably as well. The sustainable production of these energy carriers is dependant of the capacity of the electricity network and the availability of resources. The topic of clean energy and electricity was mentioned by a few of the interviewees, but it is difficult to make a clear pathway for this topic based on the findings from the interviews. Furthermore, this topic is outside of the scope of this research. Nevertheless, the production of clean energy and creating the capacity on the electricity net need to be considered in the transition towards climate neutral transportation.

6 Discussion

6.1 Key findings

The research was based on conducting and interpreting interviews. The key findings of this research will first be summarised shortly. First of all, the initial vision of making the train the main mode of group travelling in the EU will be difficult to reach and is even seen as an undesirable vision for working towards a climate neutral transport sector. A modal shift from aviation to rail transport will contribute towards climate neutral transportation, but there are several reasons why this is not the ultimate solution. One reason is that constructing more new rail lines is not sustainable and therefore not desirable. Another reason is that aviation is still seen as an important part of the transport sector and at some points indispensable. An adapted vision was formulated: Group travel in the EU will be climate neutral in 2050. For this vision an elaborate pathway was formulated. Besides the modal shift towards the train, investments are needed for the aviation sector to become climate neutral. For the modal shift to happen, travelling by train needs to become more attractive and travelling by airplane needs to be discouraged. An important way of doing that is by using pricing policies in which train tickets become cheaper and plane tickets become more expensive. Furthermore, the travel experience of rail transport needs to be improved by reducing travel times, reducing waiting time during transfers, and improving the connection of infrastructure from train stations to the final destination. Finally, the process of booking international train tickets needs to be simplified. An overarching booking system for the total European rail network has to be made.

The main stakeholders in reaching this vision are identified during the interviews. One important group are the public or the travellers. They make the choice when, how, and if they travel. Their choice is based on generalised transport costs, consisting out of the costs, travel time, comfort, and on the ease of travelling with a certain modality. To change their behaviour, incentives need to be formulated to improve the attractiveness of sustainable travel options. In general, they will not choose the sustainable alternative based on responsibility by themselves as long as the generalised transport costs for the unsustainable option are lower. Governments, on a European level, national, and regional can play an important role in creating incentives for the public. This can be done by implementing policies, levying taxes, granting subsidies, and put-up restrictions in order to make the airplane less attractive, with the consequence that the attractiveness of the train improves. The rail operators are the stakeholders that can improve the rail services, by abiding to the policies implemented, and cooperating with other national rail operators to introduce good international train routes on existing rail. Businesses can play a role by taking their corporate social responsibility and encouraging their employees to travel in a sustainable way, by working from home, and meeting online, in order to reduce the amount of travel movements caused by work related travelling. Next, airlines and airports need to change their business model to make this transition possible. Restrictions from the government, as well as taxes on aviation fuels and plane tickets can make travelling by airplane less attractive, leading to shrinking of the aviation sector. Besides that, the aviation sector has to work towards sustainability by researching and implementing sustainable aviation techniques.

6.2 Interpretation of the results

Vision and interventions

The input from the interviews has been formulated into intervention pathways in chapter 5, in which the results are already interpreted in a way but can also be seen as a part of the results. The choices made for the formulation are based on the emphasis that was laid on the topics by the interviewees themselves, as well as the interpretation of these findings by the researcher. These interpretations of the researcher are based on the knowledge about the topic acquired during the execution of this research.

As is already discussed in chapter 5 and 6.1, the initial vision formulated for this research should be adapted. Every interviewee pointed out that reaching the vision of making the train the main mode of group transportation in the EU in 2050 is very difficult to reach. Some interviewees even indicated that it is undesirable to work towards this vision when looking at the bigger goal of climate neutral transportation.

The vision that was formulated before the interviews were conducted was based on the ambitions of the European Union to become climate neutral. One of the goals was for the HSR network to be tripled by 2030 in Europe and that the majority of medium haul passenger travel has to go via rail in 2050 (European Commission, 2011). What became clear from the interviews is that in the first place the timeframe given to reach this goal is not long enough. In order to triple the HSR network by 2030 the infrastructure has to expand, and construction of rails takes a long time to complete. Also, the timeframe of 2050 to make the train the main mode is too short. Interviewee 3 worded it very nice: If you want to get a sense of the order of magnitude of the dynamics look forward for a certain period of time, and then look back for an equal amount of time: 2050 is in 30 years. To elaborate, looking back at the changes for the transport sector in the past 30 years, not many major or impactful changes have been made. When these goals for increasing travelling by train have to be reached, or even the bigger goals of reaching a climate neutral Europe, stronger policies have to be put into place.

Besides the question whether the vision formulated in this research is reachable, the interviewees questioned the desirability of making the train the main mode of transportation. One of the interventions that need to be done to make the train the main mode is to expand the rail network in order to accommodate more travelling by train. There are, however, several points of attention with regard to the sustainability for the construction of new rail lines. Construction of rail itself emits GHGs. Land use and noise pollution are other sustainability issues that need to be taken into account for the construction on new rail.

Another barrier concerning the construction of rail lines are the huge investment costs. The investments needed for increasing the rail network in the EU could and maybe should be spend on other ways of working towards climate neutral transportation. Climate neutral aviation is one of those options, which during the interviews is mentioned as a serious option. Since the train can already be run climate neutral, or at least more sustainable than airplanes, this is a serious dilemma. For travel movements to stay at the level they are now, while shifting from aviation to rail transport, more capacity is needed on the rail network, and constructing new rail lines is inevitable. The need for newly constructed rail lines is one of the main reasons why making the train the main mode is not desirable when working towards a climate neutral transport sector. Both the construction of new rail lines as the implementation of sustainable airplanes are interventions for the long, or even the very

long-term. To reduce emissions from the transport sector at this point in time, less people need to travel.

For the investments in sustainable modes of transportation, it is important to focus on the bigger goal of becoming climate neutral, and not concentrating exclusively on the sustainability of a specific modality. Airplanes are very efficient vehicles with high speeds and a minor use of infrastructure. If it is possible to create climate neutral airplanes, that alternative would be a very good way of travelling. There is some scepticism, however, about the reachability of aviation becoming climate neutral. The techniques that are proposed to reach it are still in its infancy. Furthermore, the availability of materials used in batteries, and the huge amount of clean electricity that is needed for the production of hydrogen or biofuels are barriers for reaching sustainable aviation. Sceptics point out that these promises of aviation becoming climate neutral are empty promises from the aviation sector to keep aviation existing and distract from switching towards better options for climate neutral transport (Obbink, 2022). Whenever it is not realistic that the aviation sector becomes truly climate neutral and does not improve the sustainability of the transport sector, pushing for this innovation is not advisable.

Policies and regulations that are suggested in the pathway can be controversial and may come across some opposition for the implementation. Some policies introduced by governments have to be reviewed in order to find out whether it is legally possible to implement. Prohibiting flights, for instance, already is a legal case between Schiphol and the Dutch government (NOS, 2023). Increasing taxes and prohibiting certain types of advertisement might also meet some difficulties. During the interviews this opposition, mainly from the aviation sector, is not discussed. Strong leadership by the governments can be one requirement of dealing with this opposition. It is therefore essential to keep the dialogue alive, and to keep the aviation sector involved in the formulation of these policies and strategies. It is important to keep in mind during these formulation processes that the aviation sector will have an interest in prioritization of their own agenda. This might complicate the process of working towards sustainability, and it will make it harder to keep the aviation sector involved in these processes.

The interventions that are discussed so far are aimed at a transportation system that maintains the present broad offer of services to travellers. To make the transport system in this scenario climate neutral, the modalities have to become climate neutral. It is, however, difficult to reach climate neutrality while at the same time the same amount of travel movements is maintained. Large interventions are needed in techniques and systems to create these climate neutral modes of transportation. And the question is whether it is possible at all. The "easy" solution to work towards climate neutral transportation is to travel less. This solution has been discussed by the interviewees in the form of alternate destinations, working at home, and meeting online. For this, a change in travel behaviour, or a cultural change in general is needed. People in the EU have become accustomed to a certain standard of luxury and the possibility to travel wherever they want to go for a low price. People need to be prepared to sacrifice a certain level of luxury in order to work towards a climate neutral continent, in which the transportation sector is also climate neutral. To achieve this people will need incentives, since they will not do this by themselves.

The incentives that need to be introduced, discussed in chapter 5.2, are in line with the literature about factors that are important for making a choice in the mode of transport. Travel time, the price of tickets, and the ease of booking are all mentioned both in literature and in the interviews. In literature, travel time is seen as the most important factor for people to choose a transportation mode (Adler et al., 2010; Clewlow et al., 2014; Brida et al., 2017). In the interviews, more focus was

put on the ticket prices. It most likely is all related and it is essential that prices, travel time, and the ease of booking need to be improved for train to compete with airplane.

Stakeholders

The need for incentives to be introduced are in line with the theory of the tragedy of the commons (Hardin, 1968). The tragedy of the commons is a concept that describes a situation where a shared resource, such as a fishery or a forest, is overused and depleted due to the self-interested actions of individuals or groups. This phenomenon is often observed in sustainability problems, where the depletion of natural resources can lead to long-term environmental and economic consequences. The tragedy of the commons also applies to air pollution, where the actions of individuals or businesses can contribute to the depletion of a shared resource - in this case, clean air. To prevent the tragedy of the commons and achieve sustainability, it is necessary to establish rules and regulations that incentivize individuals and groups to act in the collective interest. The sustainability problems caused by the transportation sector can be seen as the tragedy of the commons.

In line with the tragedy of the commons, the public needs incentives in order to have them change their behaviour towards sustainable behaviour. It was also mentioned during the interviews that people do not act out of their own responsibility (interviews 1, 2, 5, 6, 7, 8, 9).

The government is the stakeholder that not only has the obligation, but also has the power to create the incentives for the public. The governments on several levels, i.e., European, national, and regional, can create incentives on different levels. Implementing policies and regulations will guide the public as well as businesses in the choices they want and have to make. The implementation of certain policies, however, is also dependent on politics. The focus points of democratically chosen leaders can differ every few years after elections. The political views on societal topics can totally be in conflict with what is suggested in this roadmap. Some political leaders focus more on economical topics and prefer the free-market forces to solve the issue without interference from the government. This political point of view can be a barrier for fast improvements on sustainability issues, as several interviewees pointed out. They pointed out that the free market will not solve these sustainability issues by itself (interviews 1, 2, 5, 8, 9). The changes in political views every few years after elections also is a barrier for the formulation of long-term goals and strategies. Governments need to show strong and powerful leadership, with interferences in the free market from their side whenever this is needed.

With regard to sustainability issues, another problem can be that people and organisations point at each other in order to stay away from the responsibility to solve these issues. Governments, large businesses, or society itself, all parties try to push off the responsibility to the other party. The tragedy of the commons in which people prioritise their own interests is a possible explanation for this behaviour (Hardin, 1968). This phenomenon was also recognisable during some of the interviews. Although all the interviewees mentioned the government as the most important stakeholder to take responsibility, they also pointed to some other parties. In those cases, the responsibility was laid (partly) at another department than the one they were working in themselves, or rail operators and the society had to play a larger role. In the end, everyone has to take a certain level of responsibility in working towards climate neutrality.

Still, I think, based on the tasks of the government, the government should play the most important role in this transition, and is able to make the largest changes. Governments have a task to create a liveable world, and sustainability is an important factor in creating, and keeping a liveable world. The

governments also have the best toolbox to enable change: policies and regulations. For international transportation, cooperation between the countries in the EU is essential. On a European level certain targets and policies for all the EU countries can be introduced. After that the national governments can implement policies in line with the European policies for their own country.

Clear policies with regard to certain longer-term goals will help the public and the businesses to understand why a change of behaviour or business practices is necessary. This helps to create stability and prevents that the public or the businesses have to live with the uncertainty whether these targets will change again in a short-term.

6.3 Methodology

For coding the interviews, many codes were created while coding the interviews. The benefit of this way of coding was that the codes could be tailor made for a specific part of the text. However, the downside of this way of coding was that there was no real guideline at the start to come up with the codes and group them. This was done after the coding of the interviews, and certain quite specific codes had to be put together into groups. Because of the lack of a real guideline in creating the codes at the start, analysing afterwards became a little harder. Creating guidelines and code groups before the coding itself would have made the coding process as well as analysing the codes afterwards easier. Although it was possible to formulate the codes during the coding itself, with the use of a guideline, better choices could have been made for the formulation.

The data for this research has been gathered by interviewing experts on relevant topics. These experts had knowledge about policies and about the train side of this research. Aviation experts were less involved in this research, mainly because of time constraints, but also because the focus first was solely on the train. The input of aviation experts, however, could have given another perspective on the possible pathways towards climate neutral transportation. This also counts for the input of technical experts in the field of transportation techniques, who also could have given insights in the possibilities for aviation to become sustainable and the timeframe for instance. Furthermore, a follow-up with the experts interviewed could give more input by means of feedback on the proposed pathways and new insights on potential other focus points.

6.4 Scientific contribution

This research has a scientifical contribution mainly on two fronts: Policy and decision-making support, and developing new methods. In a lesser degree, the findings from this research can also be seen as a contribution to solving real world problems, but to really solve them, more research is needed and the findings from this research have to be implemented.

First of all, the results of this research, the findings from the interviews and the formulated pathways can be seen as a policy and decision-making support. Governments are identified as the main stakeholder for reaching the vision that was formulated for the backcasting analysis, and the formulated pathways contain a lot of policy related interventions. These pathways can be used as a guideline for policy-makers when they want to reach the vision of making the train the main mode of transportation within Europe. Also for other goals, related to sustainable transportation, inspiration

can be drawn from these pathways by policy makers, as certain interventions can be applicable and useful for other transport related sustainability issues.

The development of new methods is another scientific contribution that comes from this research. The methodology used in this research for the backcasting analysis is different from what most other studies on transportation have done. First of all the focus in this research is on the formulation of the pathways towards the future vision. This research used pre-determined visions, stated by others, in this instance the European Union, which makes it more applicable for the real world, as these goals exist already. As stated by Geurs & van Wee (2004), most backcasting analysis do not focus a lot on the pathways, which is done in this research.

Besides the focus on the pathways, the choice to interview experts on the relevant areas of expertise is also something that has not been used a lot for transport related backcasting studies. As Soria-Lara and Banister (2018) argue in their backcasting study, an implementation gap exists between the academic backcasting analysis and the real transport practices. This is due to the focus being on the formulation of the pathways and the policy-packages with input from a small group of stakeholders, but less on the implementation of them and the acceptability. They want to solve this implementation gap by focussing more on the later appraisal phase with the input of several experts assessing the formulated pathways.

In this research, the input of experts is already used in the formulation of the pathways themselves. Other than Soria-Lara and Banister (2018), not only policy makers are involved as experts, but also people with expertise in areas like transport and behavioural change. I want to argue that the input of experts with a broad spectrum for the areas of expertise already used for the formulation of the pathways can also solve to the implementation gap of policy packages to some extent. When input is given by these experts in the formulation of the pathway phase already, a less extensive appraisal phase might be needed. I think the input of a wide range of experts in the different phases of a backcasting analysis can be of use to close the implementation gap. In which phase this input is needed depends on the scope of the research and on what the issue at hand is.

As backcasting is already seen as a useful method to tackle sustainability problems (Barrella and Amekudzi, 2011, Dreborg, 1996), when the policy packages formulated by backcasting analysis can be implemented in the real world, it can be used to solve real world problems.

7 Conclusion

This research has tried to answer the research question: *What implementation pathways are foreseeable to replace air passenger transport with high-speed rail within Europe?* By performing a backcasting analysis these pathways were formulated. First of all the vision for the backcasting analysis was formulated based on already existing goals of the EU: *In 2050 the train will be the main mode of transportation for group traveling within the European Union and is a climate neutral way of transportation.*

Input from experts with several areas of expertise lead to the insight that the vision formulated will be very hard to reach and might not be desirable. The desirability of reaching the vision being questionable was based on the high investment costs for the construction and maintenance of rail infrastructure. Also the GHGs emitted by construction made it less desirable.

Taking this into account for the formulation of the pathways, the focus of the interventions towards making the train the main mode are on three things: discouraging travel by airplane, improving the efficiency of the existing rail infrastructure, and improving the soft factors of train services.

The discouragement of aviation should be the number one priority to increase travelling by train. Discouraging aviation by increasing the prices of plane tickets and decreasing the number of available flights can help in achieving a shift from aviation towards more sustainable modes of transportation like the train. The travel costs are one of the main reasons people make a choice in transportation mode.

At the start, the main focus of this research was on the extension of the possibilities of the train network in order to go towards climate neutral transportation. However, the interviews made clear that the focus needed a shift.

The main takeaway from this research is that making the train the main mode of transportation is not the only way to go towards climate neutral transportation. The most important reason for this change of view is that an attractive train network needs new rail. The construction of new rail meets many barriers and has negative impacts on the environment. A modal shift towards the train is nevertheless an improvement with regard to the GHG emissions caused by the transport sector. In the EU the rail network is to a great extent already electrified. With the use of clean electricity, travelling by train already is a major improvement compared to travelling by airplane. To establish this modal shift, the focus should not be on constructing newer rail, but on increasing the capacity on the existing rail network, as well as on improving the soft factors of travelling by train. Improving the capacity and the soft factors can be done in several ways. It can be done by constructing very efficient timetables for the trains to run on, in which international trains are given a higher priority, international night trains are introduced, travel time is being reduced, and waiting times during transfers are minimalised. The implementation of ERTMS and working with uniform rail systems throughout the EU will also improve the efficiency of the rail network. Also, the introduction of an overarching booking system for international train tickets is needed. At this point in time, it is difficult, or even almost impossible to book tickets for certain international routes. Booking tickets for international train travels should be as easy as booking a plane ticket.

Furthermore, ticket prices for the train have to become competitive with the prices of plane tickets. This can be realised by subsidising train tickets, as well as by lowering taxes on the energy used by trains. On the aviation side, tickets have to become more expensive. The polluter has to pay. The introduction of an emission trading system can help in two ways. It can ensure that sustainable

practices are more profitable, and it will make polluting practices more expensive. Levying taxes on aviation fuels and stopping investments in the fossil fuel industry can also lead to an increase of the price of plane tickets.

Besides the modal shift from aviation towards rail transport, a behavioural change is needed for people to choose the sustainable alternative. Parts of this behavioural change towards sustainable behaviour can be that people choose the train instead of the airplane. But also the choice for destinations closer to home, work from home, or meet online. These choices lead to less travel movements, which leads to a decrease in GHG emissions from the transport sector.

For the long-term, new transport techniques could be developed that are climate neutral. One of these innovations could be sustainable aviation, in which airplanes are powered by clean energy sources. Aviation is a very efficient way of transportation because of the travel speed, the absence of infrastructure in the air, and the easy reachability of all kinds of destinations. Climate neutral aviation would therefore be an ideal mode of transportation. Investments need to be made to develop sustainable aviation techniques. This is however something for the long-term, as the development of these techniques is still in its infancy, and the amount of energy needed to run airplanes on clean energy sources is huge. To work towards a climate neutral continent, and a climate neutral transportation sector, the number of flights in the short-term has to be reduced drastically.

Governments have a leading role in realising a climate neutral transport sector. The toolbox of policies and regulations they can use will guide the public and businesses towards more sustainable practices. Implementation of policies, levying taxes, and granting subsidies can level the playing field between aviation and train travel, and establish a change in travel behaviour. Governments need to show strong leadership in order to reach the goal of climate neutrality and also need to be prepared to face fierce opposition from the aviation sector and the fossil fuel industry.

This research has scientifically contributed as a policy and decision-making support by formulating pathways towards the vision of making the train the main mode of transportation in Europe in the fight against climate change. Policies and implementation pathways are formulated, and can be used as a support in reaching this goal, but also as inspiration towards reaching other transport related sustainability goals.

Furthermore, the method used by using input from experts from several areas of expertise, can close the implementation gap of the policy packages in the real world, which can be a solution for a shortcoming of backcasting identified by Soria-Lara & Banister (2018). By increasing the involvement of stakeholders and experts in backcasting research for the formulation of the pathways as is done in this research, but also in the evaluation of the vision and pathways, the implementation gap between the academic backcasting and the real world transport practices can be closed.

Limitations and recommendations

The focus of this research is mainly on substituting aviation with train. GHG emissions from the transport sector, however, are mainly caused by private car usage. For climate neutrality of the transport sector, cars also need to become climate neutral, or have to be replaced by a sustainable transportation mode. The focus in this research was not on the car, as this research was focussed on group travel. Cars are not used for transport of larger groups, as planes and trains do. Another study needs to investigate what needs to be done to decrease the emissions caused by cars, or to establish

a modal shift from cars to other modalities The backcasting analysis method, used in this research, can be a useful model for that modal shift as well.

Input from passengers themselves could also be a worthwhile addition to this research and help to give further insights in travel behaviour. This can be done by means of conducting surveys with a large sample size. Such further research could give insights in the barriers for passengers changing their travel behaviour towards sustainable transportation. Although there are earlier studies on this topic (Brida et al. 2017; Sinha et al., 2020), an addition from a sustainability perspective regarding these barriers for travel behaviour can give new insights.

As one of the scientific contributions of this research is a slightly different methodology for backcasting, to fill the implementation gap of academic backcasting and real life transport practices, this implementation gap could be filled even more by including the involvement of a lot of experts with a broad variety in area of expertise. Not only using their input in the formulation of the pathways, but also in the evaluation of the vision and the pathways themselves. Furthermore, more involvement of behavioural experts should be included as solving these issues as the one in this research are very much socially related as well. Their input is very important for the behavioural change that is needed.

When it comes to reaching sustainability, responsibility has to be taken by the organisations that have the power to change things. Several solutions to work towards climate neutrality are already identified in literature, but also in this research, and are clear in what is needed. To implement them, priorities have to shift towards sustainability, and collective action is needed. Only with strong leadership and priorities straight, a change can come about.

List of abbreviations

APT	Air Passenger Transport
EC	European Commission
ERTMS	European Rail Traffic Management System
EST	Environmentally Sustainable Transport
EU	European Union
EU-27	The 27 member states of the European Union
GHG	Green House Gas
HSR	High Speed Rail
LCA	Life Cycle Assessment
OECD	Organisation for Economic Co-operation and Development
SETA	Single European Transport Area
WTW	Well To Wheel

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Appendix A

Appendix A1

Semi-structured interview protocol in English. The formulation of this protocol is described in chapter 3.3

Interview

Thank you again for agreeing to participate in this interview. The subject of this interview is climate neutral personal transportation within Europe, with a focus on trains, specifically high speed rail. Your participation in this interview is voluntary, so you can indicate at any time that you do not want to answer a question or do not want to continue the interview. The interview will be completely anonymized. Additionally, an audio recording of this interview will be made if you give permission, do you give permission for this interview to be audio-recorded?

The goal of this interview is to lay a foundation of knowledge for intervention pathways towards climate neutral transportation within Europe, with the train as the main mode of transportation for personal transportation within Europe. The focus is on replacing flights within Europe with trains.

About you

1. Can you briefly tell something about yourself and your job/expertise area?

2. What do you think the future of personal transportation within Europe will be, especially when it comes to sustainability?

About transportation and the vision

The vision that has been formulated for this research, based on European goals, is as follows: by 2050, high speed rail will be the main method of transportation within Europe for personal transportation, in order to work towards climate neutral transportation.

3. What do you think of this goal? And is it feasible?

4. What role do regional, national and European governments play in achieving this vision?

5. Which policies could be implemented to achieve this vision?

6. What technologies could be developed, or improved, to achieve this vision?

7. What role does the consumer and the general public play in achieving this vision?

8. Are there any other actors, besides the government, technology and consumer, who can play a role in this transition?
9. What could these actors do?

10. Which actor or aspect mentioned so far plays the most important role in achieving this vision? Why?

11. Do you have anything else you would like to add?

Thank you very much for your participation, may I still contact you afterwards for any clarification about what you said, or for feedback on what has come out of this interview and other interviews?

Semi-structured interview protocol in Dutch. The formulation of the protocol is described in chapter 3.3

Interview

Nogmaals dank dat u mee wilt doen aan dit interview. Het onderwerp van dit interview is klimaatneutraal personenvervoer binnen Europa. De focus hierbij ligt op de trein en dan voornamelijk High speed rail. Uw deelname aan dit interview is vrijwillig, dus u kunt op elk moment aangeven dat u een vraag niet wilt beantwoorden of dat u het interview niet wilt voortzetten. Het interview zal volledig geanonimiseerd worden. Daarnaast zal er een audio opname worden gemaakt van dit interview als u daar toestemming voor geeft, geeft u daar toestemming voor?

Het doel van dit interview is om een basis aan kennis te leggen voor interventiepaden richting klimaatneutraal transport binnen Europa en de trein het voornaamste vervoersmiddel laten zijn voor personen vervoer binnen Europa. De focus ligt hierbij op het vervangen van vluchten binnen Europa met de trein.

Over u

1. Kunt u kort iets vertellen over wie u bent en wat uw baan/expertisegebied is.

2. Wat is volgens u de toekomst van personenvervoer binnen Europa, zeker als het om duurzaamheid gaat.

Over transport en de visie

De visie die geformuleerd is voor dit onderzoek, gebaseerd op Europese doelen is als volgt: in 2050 zal high speed rail de voornaamste vervoersmethode zijn binnen Europa voor personenvervoer, dit om richting klimaat neutraal transport toe te werken.

3. Wat vindt u van dit doel? En is het haalbaar?

4. Welke rol spelen regionale, nationale en europese overheden in het bereiken van deze visie?

5. Welk beleid, of welke beleidsvorming zou geimplementeerd kunnen worden om deze visie te behalen?

6. Welke technologieën zouden ontwikkeld kunnen worden, of verbeterd kunnen worden om deze visie te behalen?

7. Welk aandeel heeft de consument en het algemene publiek in het behalen van deze visie?

8. Zijn er nog andere actoren, naast de overheid, techniek en consument, die een rol in deze transitie kunnen spelen?

9. Wat zouden deze actoren kunnen doen?

10. Welke actor of aspect die tot nu toe genoemd is speelt de belangrijkste rol in het behalen van deze visie? Waarom?

11. Heeft u nog iets wat u nog wilt toevoegen?

Heel erg bedankt voor uw deelname, zou ik u nog mogen benaderen hierna met eventuele opheldering over wat u gezegd heeft, of voor feedback vragen over wat er uit dit interview en andere interviews is gekomen?

Appendix B

Table of mentioned topics during interviews with the number of times it was mentioned and in which interview. These topics are part of the basis of the results and the following pathway described in chapters 4 and 5 respectively.

Behaviour

some people do act on responsibility

Code name	Times mentioned	Interviews
a group of people that lead by example to establish behavioural change	1	9
individuals could point out to their employer they have a corporate social responsibility	3	3,6,9
some people are also considering social-cultural issues for the transport choice	3	3,6,9
the public is allready more aware of climate change and wants to do something about it	6	1,3,6,7,8,9
Total	13	

identify the barriers why people do not change their behaviour

Code name	Times mentioned	Interviews
target different groups with different interventions	1	9
what are the barriers for people not to perform the wanted behaviour	2	9
How can behaviour be influenced in a way you want	2	9
behavioural experts could play a role in how to enable behavioural change	3	1,9
demographics of a country or region play a role in modality choice and demand for transport	2	3,5
geographical and urban structure influences the choice of transport mode	1	5
Total	11	

Behavrioural aspects

Code name	Times mentioned	Interviews
businesses need to enable behavioural change	6	1,3,6,8
governments need to enable behavioural change	14	1,3,7,8,9

people dont want to be told what they have to do and might act against it	1	1
people feel guilty about taking the airplane	5	1,2,3,8
people will not act on responsibility but need incentives to change their behaviour	15	1,2,5,6,7,8,9
raising more awareness among the public about sustainability will not work	2	2,9
when a modal shift is incentivised from plane to rail and the train becomes the main mode, travel behaviour will change	2	4,8
Total	45	

Influences on travel behaviour/Generalised transport costs

making the train more attractive

Code name	Times mentioned	Interviews
the train is a good place for people to work during travelling	2	6,8
make train an attractive alternative for aviation	17	1,4,5,6,7,8
Total	19	

booking of tickets becoming more easy

Code name	Times mentioned	Interviews
claims when something goes wrong needs to be handled by an overarching organisation	2	4,6
data about the timetable needs to be shared with third parties	3	4,6
booking of international tickets is only possible short before a new timetable is released	1	4
booking of tickets for trains needs to be simplefied	11	1,3,4,6,7
Total	17	

soft factors have improved first

Code name	Times mentioned	Interviews
focus first on soft factors before constructing more rail	2	3
soft factors like service, ticketing and information need to become better for trains	6	3,4,8
Total	8	

multimodality and door-to-door

Code name	Times mentioned	Interviews
multimodal traveling is needed to reach your destination and to spread the load on the transport network	5	5,6,8
transfers from station or airport to final destination are important	2	3,4
the complete door-to-door travel time has to be better for train	4	3,7
optimise the different modalities and let them work together (multimodal)	3	8
multimodal transfers need to become more easy (airplane to train)	3	6,8
destinations can choose where to build an attraction or provision	1	3
Total	**18**	

Choice of destination and travel frequency

Code name	Times mentioned	Interviews
promote destinations closer to home and target people closer to the destination	3	4
destinations far away will not bring you a better vacation than a destination closer to home per	2	4
the choice of destination depends on supply and is not pinned on forehand	4	3,4,8
travel less when it is not necessary, especially in the business market	6	3,5,8
design urban areas in a way that less travel movements are required	1	5
Total	**16**	

generalised transport costs

Code name	Times mentioned	Interviews
people base their choice of transport on money, time and other factors (generalized transport costs)	6	3,5,7,8,9
money and time play crucial roles in the choice	4	1,5,8
train can not compete with aviation because of price, ease of booking and/or speed	11	1,2,4,6,7,9
time in train is very important for making train attractive	5	2,4,7,8,9
travel time with train is a big barrier for long distances	2	2,8

when trains are frequently delayed or cancelled, train becomes less attractive	3	7,9
transfers between trains have to be connected well	5	1,4,7,9
governments need to subsidise train	6	1,6,7,8,9
train needs to become cheaper	10	1,6,7,8,9
Total	52	

Aviation

Aviation becoming more expensive and disencouraged:

Code name	Times mentioned	Interviews
pricing on GHG emissions that are paid by the polluters, emission trading system	6	5,8
value added tax on flight tickets	2	3,8
aviation gets a lot of financial benefits and supports	5	3,7,8
less capacity on airports creates scarcity and will increase prices for flights	1	2
pricing on aviation fuels	6	2,3,8
aviation needs to become more expensive	20	1,2,3,4,7,8,9
aviation must be disencouraged	8	1,3,4,7,8,9
governments have not so much power to prohibit or discourage things in aviation	3	8
prohibit very short flights	3	2,3,8
Total	54	

aviation is a very efficient transportation mode

Code name	Times mentioned	Interviews
aviation is a liberalised sector	3	8
the timetable of airplanes is very flexible for booking	1	4
because the capacity in airplanes is lower than in trains, it is easier to offer flights to smaller airports as the airplane will be filled anyway	1	4
aviation is very efficient way of transportation	3	4,5,8
Total	8	

aviation needs to become climate neutral

Code name	Times mentioned	Interviews
green fuels in airplanes	2	3,4
hydrogen airplanes	1	3
sustainable aviation has to be considered as a way of reaching climate neutral transport	10	3,4,5,6,8
electric airplanes will only be interesting on the very long-term	2	2,8
Total	**15**	

longer flights are a problem

Code name	Times mentioned	Interviews
intercontintental flights are hard to replace with train	5	2,5,6
short flights dont contribute relatively speaking a lot to co2 emissions	4	2,3,4
intercontinental flights contribute the most to GHG emissions from the aviation sector	6	3,4,8
certain destinations cannot be reached by train, for instance islands	2	2,4
Total	**17**	

Other

Code name	Times mentioned	Interviews
the lobby for aviation is very strong	1	3
Total	**1**	

Train

Rail operators (working together)

Code name	Times mentioned	Interviews
(european) government need to enable cooperation between national rail operators	3	6,7
governments need to set quality standards that rail operators must meet	9	2,3,4,6,7
competition between rail operators could make rail more efficient	1	8
rail operators need to work together	4	3,4,6,7
competition between rail operators has led to conflicts between them	1	2
rail operators are not willing to work together at this point in time for international train routes	7	2,4,6,7
international competition on rail is less problematic	1	2

the focus of rail operators is on national train routes	7	2,4,6,7,8
Total	**33**	

construction of infrastructure

Code name	*Times mentioned*	*Interviews*
governments need to invest in good infrastructure	3	6,7,9
governments (national and european) can research which trajects should be introduced for train	5	3,4,6,8
direct connections between every destination is not desirable for train	1	4
for some trajects, rail needs to be constructed to become competitive with airplane	7	3,4,6,8
electrificating the railnetwork needs to take place throughout europe	6	1,3,4,8
infrastructure will be in its place for a very long time	2	1
Total	**24**	

Barriers for and cons of constructing train infrastructure

Code name	*Times mentioned*	*Interviews*
construction and innovation of infrastructure for train takes a long time	10	1,2,5,7,8
construction and maintenance of railinfrastructure are lots of people needed for	3	1,7
construction and maintenance of rail infra specialistic knowledge is neede	3	7
construction and maintenance of infrastructure is very expensive	3	5,8
construction of rail infra causes lots of GHG emissions	6	4,5,7,8
suppliers of construction materials for rail need to become sustainable as construction is very bad for environm	4	1,4,7,8
the landuse of railinfra is big and can be a problem	6	7,8
Total	**35**	

more efficient rail network

Code name	*Times mentioned*	*Interviews*
autonomous driving trains can increase the efficiency of the rail network	1	7
ERTMS can increase the efficiency of the railnetwork	6	6,7,8
on international train routes, fewer stops have to be on the traject to decrease travel time	2	4,8
use the existing rail network more efficiently to increase capacity on rail	20	4,6,7,8

railsystems within europe need to become uniform	4	1,7
Total	**33**	

night trains

Code name	*Times mentioned*	*Interviews*
nighttrains that use HSR speeds	1	2
nighttrains are a usefull addition to the trainnet	5	2,4,8,9
Total	**6**	

capacity in trains

Code name	*Times mentioned*	*Interviews*
rail operators keep capacity low to fill the train completely and maximise profit	2	2,4
prohibit the reservation of seats on busy train routes	2	2
trains are full because more people want to travel by train then there are available train tickets	1	2
Total	**5**	

Sustainability

sustainability gets more important

Code name	*Times mentioned*	*Interviews*
governments need to enable the production of clean energy	1	3
policies will become more focused on sustainability	3	3,9
suppliers of construction materials for rail need to become sustainable as construction is very bad for environm	4	1,4,7,8
transport needs to become more and more climate neutral. A modal shift towards sustainable transportation	10	1,3,4,6,7,8
electricity needs to be produced in a sustainable way	5	3,4
producing more clean energy will also make other modalities more sustainable	1	3
speed needs to be adapted to energy efficiency	1	4
Total	**25**	

promotion of sustainable alternatives

Code name	*Times mentioned*	*Interviews*
overarching sector organisations that promote sustainability within their sector	3	1,3,8

	Times mentioned	Interviews
third parties and travel agencies can play an important role in promoting the train	5	1,4,8
marketing and advertisement needs to focus on sustainable options	2	1,8
worldwide lobby for aviation needs to become focussed on sustainability	1	3
promote destinations closer to home and target people closer to the destination	3	4
Total	**14**	

Other

Code name	Times mentioned	Interviews
climate neutrality is the final goal, making train the main mode of transportation is a way of reaching it	2	3,8
train is not the solution against climate change	2	5,8
every flight replaced by train is a step towards climate neutrality as trains can be climate neutral	4	4,8
noise and vibrations caused by transport are not remedied by more trains	1	2
Total	**9**	

Stakeholders

Political and policy side of things

Code name	Times mentioned	Interviews
politics can be a barrier to work towards sustainability	2	5,9
priorities of countries are different	4	5,8
governments have to show powerfull leadership with strong policies	10	2,3,4,6,7,8,9
a key task of governments is to accomplish and work towards a liveable world/country/continent	3	2,5,8
governments need to set clear goals for the long-term so people and businesses know what to expect	6	1,3,4,6
Total	**25**	

working together

Code name	Times mentioned	Interviews
countries need to work together	4	1,5
(european) government need to enable cooperation between national rail operators	3	6,7
there is a large network of stakeholders involved in this transition	3	1,3,5
different organisations, businesses and governments need to work together	9	1,3,5,6,7,8
rail operators need to work together	4	3,4,6,7
Total	**23**	

Other

transport trends

Code name	Times mentioned	Interviews
a shift towards faster transport modalities takes place	1	3
aviation grows a lot if the market stays as it is	3	2,4,8
cars will become electric	2	4,7
intercontinental flights with a transfer will go by train within europe	7	1,6,8
more cargo and passengers will be transported via rail	2	7,8
the trains themselves will not become much more improved	1	3
the use of cars stays somewhat the same, but depends on income	1	3
total time spend on transportation will stay roughly the same	1	3
Transport will always be needed and will grow	3	1,2,8
transportation will grow, especially over longer distances	5	3,4,7
Total	**26**	

Other

Code name	Times mentioned	Interviews
academia can give usefull insights how to tackle certain problems	1	5
businesses exists because of making money and dont want to earn less money	4	1,5,7
connecting airports to train could bring more passengers to the airport	1	3
hyperloop is not very realistic that is will become a reality	2	2,3
hyperloop might be an interesting innovation	5	1,2,3,7,9
innovations will be inniated from outside the system and change the behaviour	1	8
the market will not solve this without incentives to earn money from sustainability	5	1,2,8,9
trains on batteries or hydrogen can be a solution on places where rail is not electrified	3	4,8
Total	**22**	

Behaviour

some people do act on responsibility

Code name	Time *men…*
a group of people that lead by example to establish behavioural change	1
individuals could point out to their employer they have a corporate social responsibility	3
some people are also considering social-cultural issues for the transport choice	3
the public is allready more aware of climate change and wants to do something about it	6
Total	**13**

identify the barriers why people do not change their behaviour

Code name	Time *men…*
target different groups with different interventions	1
what are the barriers for people not to perform the wanted behaviour	2
How can behaviour be influenced in a way you want	2
behavioural experts could play a role in how to enable behavioural change	3
demographics of a country or region play a role in modality choice and demand for transport	2
geographical and urban structure influences the choice of transport mode	1
Total	**11**

Behavrioural aspects

Code name	Time *men…*
businesses need to enable behavioural change	6
governments need to enable behavioural change	14
people dont want to be told what they have to do and might act against it	1
people feel guilty about taking the airplane	5
people will not act on responsibility but need incentives to change their behaviour	15

raising more awareness among the public about sustainability will not work	2
when a modal shift is incentivised from plane to rail and the train becomes the main mode, travel behaviour will change	2
Total	**45**

Influences on travel behaviour/Generalised transport costs

making the train more attractive

Code name	*Time menti...*
the train is a good place for people to work during travelling	2
make train an attractive alternative for aviation	17
Total	**19**

booking of tickets becoming more easy

Code name	*Time menti...*
claims when something goes wrong needs to be handled by an overarching organisation	2
data about the timetable needs to be shared with third parties	3
booking of international tickets is only possible short before a new timetable is released	1
booking of tickets for trains needs to be simplefied	11
Total	**17**

soft factors have improved first

Code name	*Time menti...*
focus first on soft factors before constructing more rail	2
soft factors like service, ticketing and information need to become better for trains	6
Total	**8**

multimodality and door-to-door

Code name	*Time menti...*

multimodal traveling is needed to reach your destination and to spread the load on the transport network	5
transfers from station or airport to final destination are important	2
the complete door-to-door travel time has to be better for train	4
optimise the different modalities and let them work together (multimodal)	3
multimodal transfers need to become more easy (airplane to train)	3
destinations can choose where to build an attraction or provision	1
Total	**18**

Choice of destination and travel frequency

Code name	*Time men*
promote destinations closer to home and target people closer to the destination	3
destinations far away will not bring you a better vacation than a destination closer to home per	2
the choice of destination depends on supply and is not pinned on forehand	4
travel less when it is not necessary, especially in the business market	6
design urban areas in a way that less travel movements are required	1
Total	**16**

generalised transport costs

Code name	*Time men*
people base their choice of transport on money, time and other factors (generalized transport costs)	6
money and time play crucial roles in the choice	4
train can not compete with aviation because of price, ease of booking and/or speed	11
time in train is very important for making train attractive	5
travel time with train is a big barrier for long distances	2
when trains are frequently delayed or cancelled, train becomes less attractive	3
transfers between trains have to be connected well	5
governments need to subsidise train	6
train needs to become cheaper	10

Total	**52**
Aviation	

Aviation becoming more expensive and disencouraged:

Code name	Times mentioned
pricing on GHG emissions that are paid by the polluters, emission trading system	6
value added tax on flight tickets	2
aviation gets a lot of financial benefits and supports	5
less capacity on airports creates scarcity and will increase prices for flights	1
pricing on aviation fuels	6
aviation needs to become more expensive	20
aviation must be disencouraged	8
governments have not so much power to prohibit or discourage things in aviation	3
prohibit very short flights	3
Total	**54**

aviation is a very efficient transportation mode

Code name	Times mentioned
aviation is a liberalised sector	3
the timetable of airplanes is very flexible for booking	1
because the capacity in airplanes is lower than in trains, it is easier to offer flights to smaller airports as the airplane will be filled anyway	1
aviation is very efficient way of transportation	3
Total	**8**

aviation needs to become climate neutral

Code name	Times mentioned
green fuels in airplanes	2

hydrogen airplanes	1
sustainable aviation has to be considered as a way of reaching climate neutral transport	10
electric airplanes will only be interesting on the very long term	2
Total	**15**

longer flights are a problem

Code name	Times mentioned
intercontintental flights are hard to replace with train	5
short flights dont contribute relatively speaking a lot to co2 emissions	4
intercontinental flights contribute the most to GHG emissions from the aviation sector	6
certain destinations cannot be reached by train, for instance islands	2
Total	**17**

Other

Code name	Times mentioned
the lobby for aviation is very strong	1
Total	**1**

Train

Rail operators (working together)

Code name	Times mentioned
(european) government need to enable cooperation between national rail operators	3
governments need to set quality standards that rail operators must meet	9
competition between rail operators could make rail more efficient	1
rail operators need to work together	4
competition between rail operators has led to conflicts between them	1
rail operators are not willing to work together at this point in time for international train routes	7
international competition on rail is less problematic	1
the focus of rail operators is on national train routes	7
Total	**33**

construction of infrastructure

Code name	Time mentioned
governments need to invest in good infrastructure	3
governments (national and european) can research which trajects should be introduced for train	5
direct connections between every destination is not desirable for train	1
for some trajects, rail needs to be constructed to become competitive with airplane	7
electrificating the railnetwork needs to take place throughout europe	6
infrastructure will be in its place for a very long time	2
Total	**24**

Barriers for and cons of constructing train infrastructure

Code name	Time mentioned
construction and innovation of infrastructure for train takes a long time	10
construction and maintenance of railinfrastructure are lots of people needed for	3
construction and maintenance of rail infra specialistic knowledge is neede	3
construction and maintenance of infrastructure is very expensive	3
construction of rail infra causes lots of GHG emissions	6
suppliers of construction materials for rail need to become sustainable as construction is very bad for environm	4
the landuse of railinfra is big and can be a problem	6
Total	**35**

more efficient rail network

Code name	Time mentioned
autonomous driving trains can increase the efficiency of the rail network	1
ERTMS can increase the efficiency of the railnetwork	6
on international train routes, fewer stops have to be on the traject to decrease travel time	2
use the existing rail network more efficiently to increase capacity on rail	20
railsystems within europe need to become uniform	4
Total	**33**

night trains

Code name	Time mentioned

nighttrains that use HSR speeds	1
nighttrains are a usefull addition to the trainnet	5
Total	**6**
capacity in trains	

Code name	Times mentioned
rail operators keep capacity low to fill the train completely and maximise profit	2
prohibit the reservation of seats on busy train routes	2
trains are full because more people want to travel by train then there are available train tickets	1
Total	**5**
Sustainability	
sustainability gets more important	

Code name	Times mentioned
governments need to enable the production of clean energy	1
policies will become more focused on sustainability	3
suppliers of construction materials for rail need to become sustainable as construction is very bad for environm	4
transport needs to become more and more climate neutral. A modal shift towards sustainable transportation	10
electricity needs to be produced in a sustainable way	5
producing more clean energy will also make other modalities more sustainable	1
speed needs to be adapted to energy efficiency	1
Total	**25**
promotion of sustainable alternatives	

Code name	Times mentioned
overarching sector organisations that promote sustainability within their sector	3
third parties and travel agencies can play an important role in promoting the train	5
marketing and advertisement needs to focus on sustainable options	2
worldwide lobby for aviation needs to become focussed on sustainability	1

promote destinations closer to home and target people closer to the destination	3
Total	**14**
Other	

Code name	Time mentioned
climate neutrality is the final goal, making train the main mode of transportation is a way of reaching it	2
train is not the solution against climate change	2
every flight replaced by train is a step towards climate neutrality as trains can be climate neutral	4
noise and vibrations caused by transport are not remedied by more trains	1
Total	**9**

Stakeholders

Political and policy side of things

Code name	Time mentioned
politics can be a barrier to work towards sustainability	2
priorities of countries are different	4
governments have to show powerfull leadership with strong policies	10
a key task of governments is to accomplish and work towards a liveable world/country/continent	3
governments need to set clear goals for the long term so people and businesses know what to expect	6
Total	**25**

working together

Code name	Time mentioned
countries need to work together	4
(european) government need to enable cooperation between national rail operators	3
there is a large network of stakeholders involved in this transition	3
different organisations, businesses and governments need to work together	9
rail operators need to work together	4
Total	**23**

Other

transport trends

Code name	Time mentioned

a shift towards faster transport modalities takes place	1
aviation grows a lot if the market stays as it is	3
cars will become electric	2
intercontinental flights with a transfer will go by train within europe	7
more cargo and passengers will be transported via rail	2
the trains themselves will not become much more improved	1
the use of cars stays somewhat the same, but depends on income	1
total time spend on transportation will stay roughly the same	1
Transport will always be needed and will grow	3
transportation will grow, especially over longer distances	5
Total	**26**
Other	
Code name	*Times men...*
academia can give usefull insights how to tackle certain problems	1
businesses exists because of making money and dont want to earn less money	4
connecting airports to train could bring more passengers to the airport	1
hyperloop is not very realistic that is will become a reality	2
hyperloop might be an interesting innovation	5
innovations will be inniated from outside the system and change the behaviour	1
the market will not solve this without incentives to earn money from sustainability	5
trains on batteries or hydrogen can be a solution on places where rail is not electrified	3
Total	**22**