Both feet on the ground
The most important determinants influencing air-rail substitution on long-distance journeys within Europe

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Preface

In front of you lies my master's thesis about air-rail substitution, the grand finale of the master's programme Human Geography. It is not a coincidence I have chosen this topic for my thesis: since I was a child, mobility and transport, especially air and rail transport, have gained my interest. During my bachelor and master studies at Utrecht University, I got the chance to further specialize in mobility, which further increased my curiosity and eager to learn more about what keeps our society moving.

During my time at Utrecht University, thinking about what the future of mobility will look like strongly had my attention. Now that humankind is facing one of its biggest challenges ever, climate change, the field of mobility changes rapidly – like many other fields, it has to become sustainable. It not only requires green vehicles, but a radical turn in the way we get from A to B too. In the end, we are – by our behaviour – responsible for the earth.

It is exactly this last point that takes a central position within this research. It has given me great pleasure writing it – which I will hope trickles down to you as reader too. I would like to thank my supervisor, Dick Ettema, for his feedback, ideas and help.

I wish you lots of fun while reading!

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Abstract

Air-rail substitution, the shift from plane to train, is highly beneficial for the environment as it has immediate effect (Dobruszkes & Givoni, 2013, p. 177). Simultaneously, right before the COVID-19 pandemic, only 10% of all public transport passengers on long-distance journeys travelled by train. The European Union acknowledges a better modal choice enables immediate action to reduce pollution by shifting to more sustainable transport modes (EC, 2021a, p. 7). However, in practice, air-rail substitution is not happening on a large scale (yet). Therefore, this research provides insight into the most important determinants influencing air-rail substitution in order to stimulate it.

Determinants influencing modal choice and therefore air-rail substitution are divided into four categories: socio-demographic, socio-psychological, spatial and journey determinants. From the literature follows that journey determinants, notably travel time and cost, have the most important effect on air-rail substitution. 79 respondents filled out an online survey including a discrete choice experiment in which respondents indicated their preference for either air or rail travel given certain travel circumstances.

From a logistic regression model follows that household composition is an important determinant of socio-demographic determinants: travelling with children reduces the chance of train use. With regard to socio-psychological determinants, the number of times travelled by train the last five years before the COVID-19 pandemic (related to experience) is important: the more trips by train, the higher the chance of rail use. Spatial determinants are relatively less important: living rural increases the chance of travelling by rail compared to living urban. However, frequency and comfort of air are the most important journey determinants: a very high comfort level of air reduces the chance of train use, while a lower frequency surprisingly also leads to a lower chance of train use. Overall, the most important determinants influencing air-rail substitution are frequency and comfort of air transport. Relatively, travel time and cost are less important. As a result, some findings are in contrast to what could be expected beforehand.

1 Introduction

Our climate is changing. Since the industrial revolution, it has done so rapidly due to us humans, as more greenhouse gas (GHG) emissions have been released into the air ever since (Rijksoverheid, n.d). This has led to a 1 degree Celsius increase in global average temperature and 20 centimetres increase of the sea level during the last 130 years. Consequences of climate change affect both people and nature in a negative way. For example, without taking action, climate change would lead to 400,000 premature deaths per year (due to air pollution) and 90,000 deaths per year (due to heatwaves as a result of global warming) only in Europe (European Commission [EC], 2019). Economic losses will be 190 billion euros if the global average temperature will rise to 3 degrees Celsius. Nature has difficulties coping with the rapid climate change: some plant and animal species risk extinction if global average temperatures continue to rise (EC, 2019).

Accounting for nearly 31% of total GHG emissions in Europe in 2019, the transport sector is a large contributor to climate change (in 2017, it was still 27%; EC, 2021c, p. 121; European Environment Agency [EEA], 2021a). Even worse, it is the only sector which has not seen a decrease in GHG emissions between 1990 and 2018 (EEA, 2020, p. 65). This is no surprise, as mobility is of growing importance in our daily lives (Hollevoet, De Witte & Macharis, 2011, p. 130). Recent measures to tackle the COVID-19 pandemic have led to a drop of transport emissions: however, it is expected that transport emissions will rebound in Europe (EEA, 2021b). International transport emissions, notably from aviation, are even projected to continue to increase without a turning point in the near future.

Awareness about the impact of climate change is growing in society. Climate change and environmental issues are seen as the main global challenges for the future by European citizens (European Parliament [EP] & EC, 2022, p. 81). The European Union (EU) acknowledges there is an urgency to act now in order to battle climate change to avoid negative consequences. It has done so by signing the Paris Agreement in 2015 and implementing a European Green Deal in 2019, a 600-billion-euro investment fund with the overarching aim of a climate-neutral Europe in 2050 (no net GHG emissions; EC, n.d.). Moreover, by 2030, already in eight years' time, the aim is to reduce net greenhouse gas emissions by at least 55% (compared to 1990 levels).

The success of the European Green Deal depends on the ability to make the European transport sector more sustainable (EC, 2021a, p. 2). For the European transport sector, the goal is to reduce transport-related greenhouse gas emissions by 90% by 2050 (EC, n.d.). To achieve this goal, the EU has set up the *Sustainable & Smart Mobility Strategy* in December 2020 as part of the Green Deal (EC, 2020). One of the three pillars of the strategy is to make sustainable alternatives widely available to enable a better modal choice, the decision process of choosing a mode of transport. The EU acknowledges that a better modal choice enables immediate action to reduce pollution by shifting to more sustainable transport modes, notably increasing the number of passengers travelling by rail (EC, 2021a, p. 7). In addition, the shift towards more sustainable transport modes must be affordable and accessible in all regions and for all passengers, stressing inclusivity (EC, 2021a, p. 17).

The EC has been very active to strengthen the position of European rail transport compared to other transport modes, as the Sustainable & Smart Mobility Strategy considers rail as a key component. Two of the Sustainable & Smart Mobility Strategy's milestones are (1) scheduled collective travel under 500 kilometres should become carbon-neutral by 2030 and (2) high-speed rail (HSR) traffic should double by 2030 and triple by 2050 (EC, 2021a, p. 10). Rail transport has significant environmental benefits compared to other modes, especially when compared to air (see figure 1). Moreover, 2021 was the European Year of Rail, during which rail was promoted as the future way of travelling (EC, 2021a, p. 8). On a national level, Germany already lowered prices on domestic long-distance train tickets by 10% at the beginning of 2020, as part of their new national climate policy (Tagesschau, 2020). At the same time, the EC acknowledges aviation's negative role in climate change and states that the aviation sector's contribution to climate enhancement needs to be strengthened significantly. The EU mentioned taxing fuel for aviation in July 2021 for the first time (EC, 2021b, p. 3). Furthermore, recently, the Dutch government announced a proposal to increase flight tax threefold, from 8 to 24 euros, which benefits the position of rail compared to air (nonetheless, a Dutch flight tax was only implemented in 2021; Lammers, 2022).

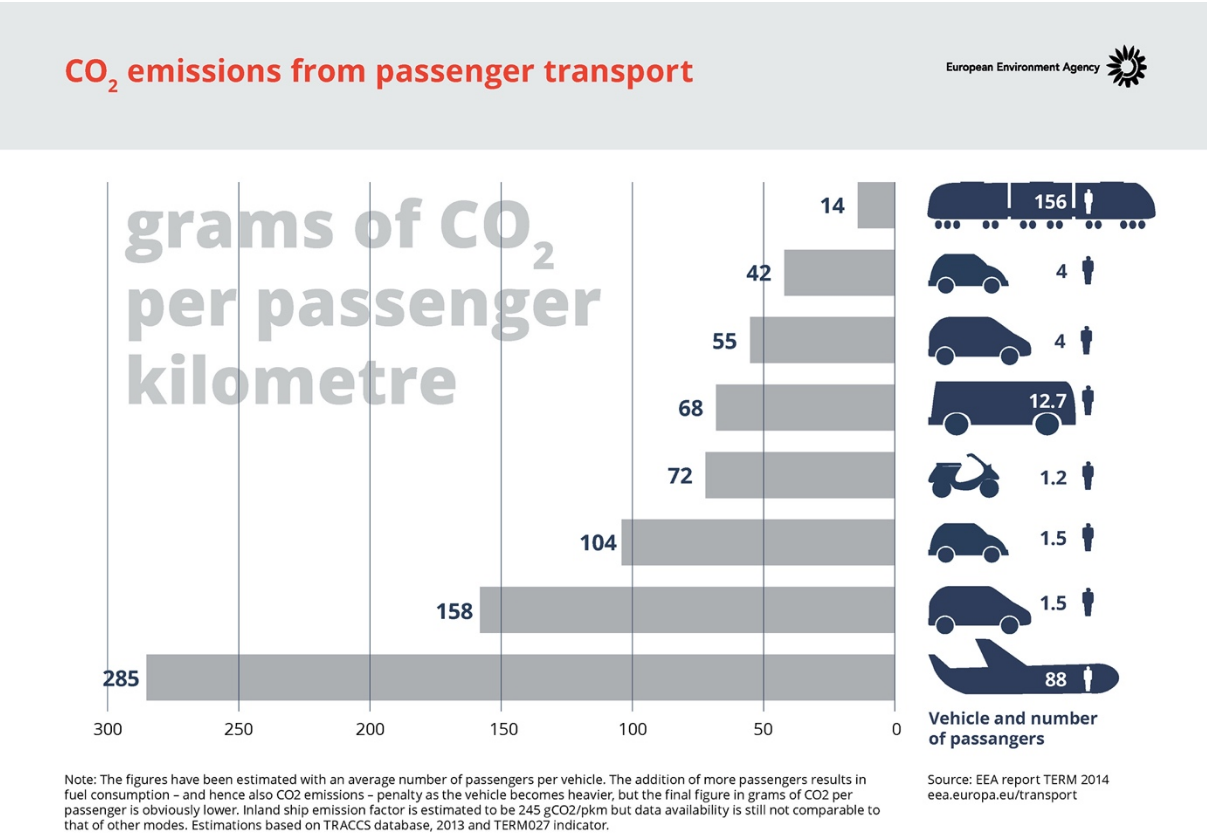


Figure 1: CO_2 emissions vary strongly between different modes of passenger transport (EEA, 2014)

As can be seen in figure 1, CO_2 emissions between air and rail transport differ enormously. Of all modes of transport, air travel contributes the most to global warming per kilometre per passenger and is therefore the most unsustainable mode of transport available (Chapman, 2007, p. 361; Dobruszkes, 2011, p. 870). Someone flying from Lisbon to New York and back generates the same level of emissions as the average person does by heating his or her home for a whole year (EC, n.d.). However, cross-border travel by public transport within Europe before the COVID-19 pandemic mainly took place by air, with rail only carrying 10% of public transport passengers (EC, 2021d, p. viii). Climate change is worry number one for EU citizens, but at the same time, they keep on contributing to climate change by frequent flying (EP & EC, 2022, p. 81).

As travel numbers are not expected to drop in the near future – on the contrary, tourism after the COVID-19 pandemic is reviving as before, reaching pre-pandemic numbers – there is a need to shift people towards more sustainable modes of transport regarding cross-border travel. This is especially important for long-distance travel within Europe (distances typically between 500 and 1000 kilometres), as it is responsible for more than 50% of climate impact

(Reichert & Holz-Rau, 2015, p. 87). The most environmentally friendly and viable option for longer distances within Europe is shifting from plane to train, called air-rail substitution (EEA, 2014). If short-haul flights would be replaced by inter-city rail travel, the environmental impact per passenger kilometre would drop by 20% (Chapman, 2007, p. 362). However, still only 6 to 7% of all passenger journeys by rail involve crossing one or more borders (EC, 2021d, p. viii). The urge for a shift from air to rail is even acknowledged by Pieter Elbers, former president-director of KLM (the largest Dutch airliner), who states that for long-distance travel in Europe, the train should be used (Duursma, 2018). Elbers pleads for fast and cheap rail connections, arguing that the international train is lightyears behind the plane – which is true with regard to passenger numbers.

If known that air transport is the most polluting mode of transport, if the EU is actively strengthening the position of rail and if even the former head of one of the largest European airliners acknowledges that the train should be the preferred mode of transport on long-distance travel within Europe, why does rail only account for 10% of all European long-distance public transport passengers? Generally, the willingness to reduce transport's contribution to climate change is present among EU citizens: electric cars and buses are appearing everywhere in the streets. Clearly, despite all efforts to promote rail travel, there is something that is holding back travellers from choosing the train instead of the plane on a large scale as rail passenger numbers lag behind. Two often named determinants of modal choice, specifically of air-rail substitution, are travel time and travel cost (Cervero, 2002, p. 266; Cho, 2013, p. 25; Kroes & Savelberg, 2019). Therefore, the EC expands HSR traffic (reducing travel time of rail) and plans to introduce a flight tax (benefiting travel cost of rail). The problem however is that air travel is still often (1) faster and (2) cheaper than rail travel, the reason why Elbers pleads for 'fast' and 'cheap' rail connections.

Air-rail substitution is highly beneficial for the environment as it has immediate effect (Dobruszkes & Givoni, 2013, p. 177). Despite the poor rail passenger numbers, in the public transport sector on European long-distance journeys, air and rail increasingly compete with each other for passengers, especially since the introduction of HSR (Behrens & Pels, 2012, p. 278). Since the beginning of this century, the HSR network has increased significantly and the number of high-speed trains almost doubled (a 95% increase between 2001 and 2019; EC, 2021d, p. 7). New HSR connections, such as Amsterdam-London (Eurostar), were introduced the last couple of years. In the couple of years to follow, new international night trains throughout Europe will be introduced (Groen, 2022). With the EU's promotion of rail and the potential taxing of air, the opportunity for air-rail substitution seems to exist in theory – however, the practice turns out to be much more complicated.

1.1 Research questions

1.1.1 Central question

The central question of this research is:

> *What are the most important determinants influencing air-rail substitution on long-distance journeys within Europe?*

1.1.2 Sub-questions

There are different determinants influencing air-rail substitution. Each sub-question will address one group of determinants, adapted from the modal choice framework of De Witte, Hollevoet, Dobruszkes, Hubert and Macharis (2013, p. 332). Socio-demographic determinants, like age and income, form the first group of determinants. Therefore, the first sub-question is:

Which socio-demographic determinants influence air-rail substitution on long-distance journeys within Europe?

Second, determinants such as awareness of climate change, norms and attitudes are grouped under socio-psychological determinants and form the second group of determinants:

Which socio-psychological determinants influence air-rail substitution on long-distance journeys within Europe?

Third, distance to an airport and access to a HSR network from a person's place of residence are spatial determinants. The third sub-question is therefore:

Which spatial determinants influence air-rail substitution on long-distance journeys within Europe?

Fourth, travel cost and time have proven to be important determinants of modal choice and therefore air-rail substitution (Kroes & Savelberg, 2019). These are typical journey determinants, which form the fourth sub-question:

Which journey determinants influence air-rail substitution on long-distance journeys within Europe?

1.2 Objective

The aim of this research is to provide insight into the most important determinants influencing the substitution of air transport by rail transport on long distance journeys within Europe, in order to stimulate air-rail substitution.

1.3 Academic and social relevance

1.3.1 Academic relevance

Modal choice, at the heart of air-rail substitution, has already been studied extensively (see De Witte et al., 2013). However, the scale of this research, modal choice of long-distance travel in Europe, and therefore cross-border travel, has not been studied in detail yet in the academic literature (Reichert & Holz-Rau, 2015, p. 88). Studies on modal choice typically focus on the commuter scale, not on the long-distance scale. Moreover, a traveller making a modal choice decision on a long-distance trip is in a very different situation than a traveller on a short-distance trip is in, because a long-distance trip involves more time and cost (Arbués, Baños, Mayor & Suárez, 2016, p. 132). Therefore, this study will contribute to the little existing literature on modal choice of (European) long-distance travel.

In line with modal choice, research on air-rail substitution more specifically has also been carried out previously. These typically focus on one corridor, for example Madrid-Barcelona (see Román, Espino & Martín, 2009), or a couple of corridors, for example Amsterdam Airport and its 13 most important destinations (see Kroes & Savelberg, 2019). These studies focus on one or more specific case studies and their results are therefore bound to these specific cases, making generalisability of the results difficult. This research does not focus on a specific corridor, but aims to study air-rail substitution in general, contributing to a small proportion of literature on air-rail substitution not related to a case study.

Most importantly, the potential for substituting air for rail transport seems to exist as HSR can successfully compete with air services (Dobruszkes & Givoni, 2013, p. 193). The last twenty years, the HSR network has been expanded extensively and more international connections will be introduced in the following years (EC, 2021d, p. 7; Groen, 2022). Still, only 10% of public transport passengers make use of the train on cross-border travel, while the plane dominates the market. The gap between potential and actual situation is still evident and therefore worth further examining in order to find the bottleneck for air-rail substitution.

With regard to EU climate policies discussed in the introduction, the European Green Deal has only been implemented in 2019, while the Sustainable & Smart Mobility Strategy has been implemented in December 2020 (EC, 2020; EC, n.d.). Moreover, the EC has opened up the international train market for competition in December 2020 and the EU has plans to tax aviation according to the EU Emissions Trading System (Ramos, 2020, p. 341; ETS; EC, 2021b, p. 3). These policies, which aim to provide environmentally friendly transport, are relatively new. Moreover, as a result, since the last couple of years, rail is actively promoted as a mode of transport on European long-distance trips. Little is known about how people's modal choice relates to the new EU policies to promote more sustainable transport. Modal choice after these new EU policies have been implemented has not been studied frequently yet, as implementation happened only recently. Therefore, this study examines if these recently introduced and potentially introduced EU policies have an influence on air-rail substitution.

Furthermore, COVID-19 has (had) a large impact on cross-border transportation and its impact on future transportation is still rather unknown. The COVID-19 pandemic may result in lasting changes in the transportation sector (EC, 2021a, p. 7; EC, 2021d, p. 54). Now that the COVID-19 pandemic is coming to an end and its effects are measurable, the effects on the transportation sector can be examined. This study is one of the first modal choice studies conducted after the height of the COVID-19 pandemic and will therefore contribute to find if any lasting changes in modal choice of cross-border travel by public transport after the COVID-19 pandemic exist.

1.3.2 Social relevance

It is not a coincidence the new EU climate policies come together with an increasing awareness in society of (the impact of) climate change. The last fifteen years have seen an increase in social awareness of climate change and sustainability. According to the database of the Dutch newspaper *Trouw*, thirty years ago, in 1992, climate change was not a hot item yet: only 12 articles contained the words 'climate change' (Den Boon, 2019). Since 2007, climate change is a recurring theme in society: that year, 304 articles contained the two words. The words 'climate activism' were only used in 2008 for the first time in an article.

Perhaps the best in-person representation of worriedness about climate change is Greta Thunberg. When she was only 15 years old, she started with a school strike in 2018 in her country of birth, Sweden, because in her eyes there would be no future for her as politicians 'destroyed' it (Grosscurt, 2021). After all, she reasoned, what is the purpose of going to school if there is no future? Her strike, called 'Fridays for Future', gained worldwide support. Eventually, she became the face of a young generation increasingly worried about the effects of climate change.

Climate change has enormous effects on all aspects of life (EC, 2019). Humans are for a large part responsible for this. There is however a growing feeling of urge among EU citizens to act now in order to prevent even worse climate change effects from occurring (EP & EC, 2022, p. 81). This research looks at modal choice, especially shifting from air to rail transport, which is a more environmentally friendly way of travelling (Dobruszkes & Givoni, 2013, p. 177). For sustainable development, research on long-distance travel, in particular air travel, is very important (Reichert & Holz-Rau, 2015, p. 103). Shifting to more sustainable modes of transport is relatively easy for humans to do and will reduce GHG emissions and therefore reduce climate change. Eventually, reducing climate change is beneficial for all humans.

With regard to air as mode of transport, the term 'flight shame' has gained attention. Flight shame is 'an individual's uneasiness over engaging in consumption that is (…) climatically problematic' (Gössling, Humpe & Bausch, 2020, p. 1). It was rapidly adopted throughout the world a couple of years ago, 'indicating a growing awareness of aviation's role in climate change' (Gössling et al., 2020, p. 1). Therefore, the probability that a person with flight shame will prefer rail above air travel is high. However, as passenger numbers of long-distance rail journeys are disappointing, there may be a mismatch between intention and actual behaviour. Although not every traveller has flight shame, they are perhaps willing to shift from air to rail in order to act environmentally friendly, but are being hold back by different factors. By understanding which determinants contribute to air-rail substitution, this research indicates the barriers preventing travellers from choosing the train over the plane, enabling individuals to act environmentally friendly.

2 Theoretical framework

This chapter gives an overview of the relevant literature of air-rail substitution on long-distance journeys. First, modal choice of long-distance trips will be discussed as air-rail substitution is in essence a modal choice. Second, more context on air and rail transport in Europe is presented. Third, studies on air-rail substitution are discussed.

It is necessary to define 'long-distance journey' more precisely, as it is a rather vague concept. What is perceived a long-distance trip by car, might be a short-distance trip by air. Some studies already regard a trip distance of 50 kilometres as a long-distance trip (see Limtanakool, Dijst & Schwanen, 2006, 2006, p. 328). In this research, long-distance trips are arbitrarily defined as trips of about 400 kilometres or more, as the highest potential for air-rail substitution lies roughly between a distance of 400 and 800 kilometres (EC, 2010, p. 11; Rothengatter, 2010, p. 319).

2.1 Modal choice

Rising mobility needs and its accompanying environmental effects have opened the debate on how to manage current and future mobility in a more sustainable way (De Witte et al., 2013, p. 329). Modal choice is a fundamental key for policymakers to improve sustainability of transportation (Arbués et al., 2016, p. 131). People's modal choice has therefore been studied frequently in scientific literature. However, there is no uniformity in definitions and methodologies applied to study the concept of modal choice (De Witte et al., 2013, pp. 329-330). It is a very complex decision process, influenced by a wide range of factors from different disciplines (economy, sociology, geography and psychology; Hollevoet et al., 2011, p. 137).

Both Hollevoet et al. and De Witte et al. define modal choice as 'the decision process to choose between different transport alternatives, which is determined by a combination of individual socio-demographic factors and spatial characteristics, and influenced by socio-psychological factors' (2011; p. 138; 2013, p. 331). Socio-demographic factors and spatial characteristics are the possibilities with regard to mobility, while socio-psychological factors influence how these possibilities are acted upon.

2.1.1 Determinants

Understanding the determinants which influence modal choice is 'important towards developing more sustainable transport systems' (Hollevoet et al., 2011, p. 129). However, as discussed earlier, modal choice determinants are not uniformly applicable. Moreover, there is a difference of modal choice determinants between short-distance trips and long-distance trips, as modal availability and travel purposes are different (Arbués et al., 2016, p. 132). Long-distance trips are usually undertaken less frequently and planned more carefully. Moreover, on long-distance trips, active modes of transport are not common, while trip purposes are typically business and leisure.

According to De Witte et al., following from their definition of modal choice, three different types of (interrelated) determinants constitute modal choice: socio-demographic, journey characteristic and space-related indicators (2013, p. 331). Socio-psychological indicators (habits, perceptions, etc.) determine how the possibilities of the three determinants with regard to modal choice are acted upon (figure 2).

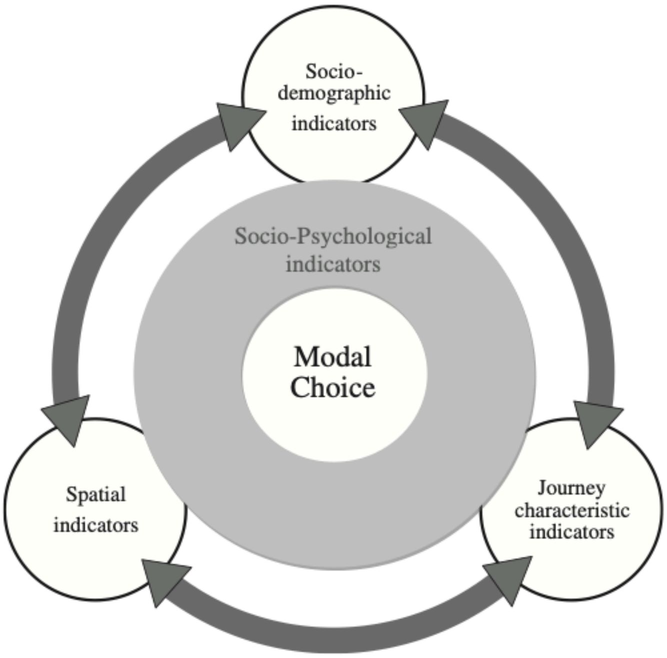


Figure 2: framework for structuring modal choice determinants (De Witte et al., 2013, p. 332)

Following De Witte et al. (2013) and Van Acker, Van Wee and Witlox (2010), four kinds of modal choice determinants are distinguished: socio-demographic determinants, socio-psychological determinants, spatial determinants and journey determinants. As a majority of modal choice studies on long-distance trips also include car use next to air and rail use, the car as mode of transport is also mentioned in this section.

Socio-demographic determinants

Socio-demographic determinants play an important role in choice of transport mode and shape the individual situation of the traveller as well as part of his or her social interactions (De Witte et al., 2013, p. 333; Arbués et al., 2016, p. 132). These determinants affect participation and distances covered in long-distance travel (Holz-Rau, Scheiner & Sicks, 2014).

There are slight differences on modal choice of long-distance travel between both **genders**. Women undertake less long-distance trips than men do (most pronounced for commuting or business purposes; Dargay & Clark, 2012, p. 578). Bhat (1997) carried out an endogenous segmentation approach to model mode choice, applied to the Toronto-Montreal corridor (distance approximately 550 kilometres). He concludes that the segment with a high proportion of males intrinsically prefers car or air travel, while the segment with a high proportion of females intrinsically prefers rail travel. Women are also less car dependent than men and are more inclined to use the train than men (Van Goeverden, 2009, p. 27; Arbués et al., 2016, p. 142). A study on modal choice of medium- to long-distance trips in a Dutch context found the same results for both genders, regardless of trip purpose (Limtanakool et al., 2006, p. 333). Nonetheless, De Witte et al. found that only in 31% of all 76 researches they reviewed, gender is significant (2013, p. 333).

Like gender, the influence of **age** on modal choice is not very clear, although slight differences are found in the literature. However, studies contradict each other: for example, Limtanakool et al. (2006) state that older adults are more likely to use the car than middle-aged and younger people. In contrast, Dargay and Clark find that for long-distance travel within Great Britain, over 60s travel less by car than under 60s (2012, p. 585). Arbués et al. found that young people and older adults rely more on the train (2016, p. 142). Georggi and Pendyala (2001) used the

American Travel Survey for an analysis of modal choice of older adults with regard to long-distance trips in the United States. One of their results is that in line with Dargay and Clark (2012), older adults are significantly less dependent on the car (Georggi & Pendyala, 2001, p. 148). Overall, there seems to be no real consensus about the influence of age on modal choice (Hollevoet et al., 2011, p. 135).

Education and **employment** are related to income. Students and employed people travel more in general according to Dargay and Clark (2012, p. 585). Students travel more by rail and less by air and car than employed people. When employed, the company's mobility policy is very important: whether a public transport pass or a car is given strongly influences an employee's modal choice (Hollevoet et al., 2011, p. 134). Limtanakool et al. found that higher educated people use public transport more frequently than the car (2006, p. 333). However, higher educated people generally have a higher income and are therefore more inclined to having access to a private car, which is in contrast to the statement of Limtanakool et al. (2006) that higher educated people use public transport more often (Hollevoet et al., 2011, p. 135). Higher educated people travel more and longer distances, especially in long-distance travel, and prefer air travel (Holz-Rau et al., 2014, p. 496; Reichert & Holz-Rau, 2015, p. 103).

Income relates positively to car use and negatively to public transport use (De Witte et al., 2013, pp. 333-334). According to Reichert and Holz-Rau, income is even one of the strongest determinants influencing modal choice (2015, p. 89). However, Limtanakool et al. are more critical and state that income does not seem to influence modal choice of journeys at least for business purposes (2006, p. 333). Car and train use increase together with income, but as the rate of car ownership is higher among higher incomes, car use will increase more than train use for long-distance travel. Air travel is the most income-elastic mode of transport on long distances in Great Britain and increases as an individual's income rises, 'suggesting it to be a luxury mode' (Dargay & Clark, 2012, p. 586). This statement is emphasized by Georggi and Pendyala, who found the same results for the United States: with rising income levels, the share of air travel steadily increases (2001, p. 148). For lower income groups, travel by road (car or bus) is higher. Arbués et al. found that a higher income leads to less public transport use over car use (2016, p. 142). In general, it tends to be the case that higher incomes are less likely to use transit and lower incomes are more influenced by the price of transport (Hollevoet et al, 2011, p. 134). Income is found significant in 61% of the papers studied by De Witte et al. and therefore among the more important determinants (2013, p. 333).

The **household composition** has clear implications for long-distance travel in Great Britain (Dargay & Clark, 2012, p. 585). Living with under 16s reduces long-distance travel, especially by train. For the United States, household size negatively effects long-distance trips (Georggi & Pendyala, 2001, pp. 137-138). Those in a single adult household travel more, especially by train and slightly more by plane. In general, as the size of a household increases, car use increases as well (Hollevoet et al., 2011, p. 135). Especially in a household with children, utility of the car increases, which leads to a decrease in use of public transport. However, a study on long-distance travel in Germany found that household size is not a very strong determinant (Reichert & Holz-Rau, 2015, p. 101). Nonetheless, in most modal choice studies, household composition is an important determinant.

Car availability has a very significant effect on mode choice for all purposes (Limtanakool et al., 2006, pp. 335-338). Probability of choosing a car increases with an increasing number of cars per driver in a household. Hollevoet et al. even regard car availability as the most important determinant influencing modal choice (2011, p. 134). Moreover, car ownership reduces the chance of taking the train by 70% when several people travel together and 55% for a single traveller (Van Goeverden, 2009, p. 27; Reichert & Holz-Rau, 2015, p. 101). In 78% of all studies considered by De Witte et al., car availability was found to be significant (2013, p. 333).

Socio-demographic determinants are often interrelated. For example, education and employment is related to income, while income is related to car availability and car availability is strongly related to modal choice. The influence of certain socio-demographic determinants on modal choice must therefore be interpreted with care.

Socio-psychological determinants

The past two decades have seen an increase in recognition that subjective elements such as perceptions and attitudes influence modal choice (De Vos, Singleton & Gärling, 2022, p. 207). Socio-psychological determinants are rather subjective. According to De Witte et al., these determinants influence how individuals act upon the other three groups of determinants and therefore influence the objective determinants (figure 2; 2013, p. 337). However, not all modal choice studies recognize the influence of socio-psychological determinants on other determinants and state that socio-psychological determinants are not related to other determinants (see Hollevoet et al., 2011, p. 132).

Habit is referred to as a repeated choice and is a very strong determinant of modal choice at the same time (Gärling & Fujii, 2009, p. 104). However, habit is an unreasoned influence of travel behaviour (Van Acker et al., 2010, p. 221). Nonetheless, a strong habit towards choosing a particular travel mode leads to less information gathering and less elaborate choice strategies (Verplanken, Aarts & Van Knippenberg, 1997). Switching to other modes of transport requires learning new routines. This is not only true for repetitive trips, but for any trip. Younger people seem to be more flexible choosing a mode of transport than older people: 'learned' habits might have gained importance over time and substitute rational decision making (Last & Manz, 2003, p. 10).

Norms and **values** determine how individuals in a society act. Norms are informal rules that guide behaviour in groups (Gossling et al., 2020, p. 2). The social norm is dependent on the acceptance or non-acceptance of friends or family (so-called *motivation to comply*; Dijst, Rietveld & Steg, 2002, p. 35). According to Eriksson, Garvill and Nordlund, awareness of adverse environmental effects can also activate a personal norm (2006, p. 16). An example of a social norm that has changed over years is 'flight shame': in earlier times, frequent flying was associated with social status, while is it now associated with pollution and climate change (hence 'shame'). Flight shame is an unease about the climate implications of air travel, related to social norms, which leads to less flying and therefore influences a person's modal choice (Gössling et al., 2020). Its appearance has grown the last couple of years, partly due to the rise of Fridays for Future.

Attitude with regard to modal choice refers to 'the degree of favourable or unfavourable evaluation or appraisal of a certain travel mode' (De Vos et al., 2022, p. 206). Travel behaviour to some extent depends on attitudes: preferences for travel behaviour are formulated based on attitudes and perceptions (Gärling & Fujii, 2009, p. 99; Van Acker et al., 2010, pp. 227-228). Usually, an attitude refers to a positive, negative or mixed evaluative response to some stimuli which influences behaviour. Flight shame for example might change an individual's attitude towards the plane.

Awareness of climate change has grown in the last couple of decades and has even lead to activism in society (Den Boon, 2019; Grosscurt, 2021). Johansson, Heldt and Johansson, who conducted a study with Swedish commuters, state that a pro-environmental behaviour can stimulate a sustainable modal choice, but previous research has shown little support for the importance of environmental criteria on modal choice (2006, pp. 508-509). Therefore, the influence of awareness of climate change on modal choice seems to be limited. Hares, Dickinson and Wilkes (2010) carried out a research on climate change and flying, involving 34 holiday travellers from the UK. They found that holiday travellers identified flying as a cause of climate change, but they did not consider avoiding to fly. An Italian study on student's awareness and modal choice also shows limited results. Informing students about environmental issues increases the propensity to use sustainable mobility, but reduces private transport usage by a small percentage of 5.8% (Cattaneo, Malighetti, Morlotti & Paleari, 2018).

As air transport numbers are likely to increase in the near future, the ability to voluntarily pay for **carbon offsets** seems increasingly popular (Gössling et al., 2007, pp. 240-241). A growing number of organisations offers an option to compensate for CO_2 emissions, possibly anticipating for future compulsory carbon trading in aviation. However, voluntary emission reductions need to increase by at least a factor 400 to achieve a 10% reduction of GHG emissions from aviation. Moreover, there is a threat that offsets make people believe that a change in travel behaviour is not necessary, while carbon offsets do not directly reduce aviation emissions. However, in a more recent study, no evidence was found that carbon offsets reduce guilt and thus boost flying (Bösehans, Bolderdijk & Wan, 2020, p. 8). Overall, voluntary carbon offsets continue to have a low uptake.

Perceptions with regard to different travel modes are important for modal choice decision making (Hollevoet et al., 2011, p. 136). Perception of for example comfort and safety for the same travel mode can be different among people. What is especially important is the perception of time and price, which can be perceived differently for alternative transport modes.

Travel time is an important determinant of modal choice. However, how time is perceived matters as well. Travel time by car is usually underestimated, while travel time by public transport is regularly overestimated, resulting in public transport generally more negatively perceived compared to the car (De Witte et al., 2013, p. 336). Moreover, people in general dislike waiting time (notably present when travelling by air), resulting in the time spent waiting perceived more negatively than in-vehicle time (time spent travelling on the mode of transport).

The same is true for travel cost. There is a difference between absolute cost perceived cost. The purchase of a car is expensive, but afterwards, remaining travel costs are relatively low. Public transport users can buy single tickets or travel passes and by paying at the point-of-use, they are more aware of the actual cost of their journey (De Witte et al., 2013, p. 337). In general, out-of-pocket costs are mainly considered when making transport decisions. Like perceived time, perceived costs lead to a perceived advantage for car use: the assessment of car costs is often subjective.

A positive or negative **experience** in the past influences the choice for a mode in the present (Hollevoet et al., 2011, p. 136). Moreover, experience can lead to familiarity, which is related to a user's knowledge about the modes of travel available (De Witte et al., 2013, p. 337). Higher mobile (and hence more experienced) individuals develop a 'modal competence' and are therefore more familiar with different modes, resulting in lower mental barriers for using alternative modes (Last & Manz, 2003, p. 10).

An individual's **lifestyle** influences other determinants of modal choice, for example decisions on education and employment, which are again related to income and car ownership (Hollevoet et al., 2011, p. 134). For example, as Dargay and Clark state, people with a higher income can perceive the plane as a luxury mode fitting their lifestyle (2012, p. 586). Lifestyle does influence modal choice, but the influence of objective socio-demographic determinants exceeds the influence of subjective lifestyles (Van Acker et al., 2010). De Vos et al. state that lifestyle may be more inherent to people than for example attitude (2022, p. 207).

Spatial determinants

On long-distance trips, few studies include land use factors, as these are typically included in short-distance mobility studies (De Witte et al., 2013; Arbués et al., 2016, p. 133). Spatial conditions however also influence modal choice of long-distance journeys due to different levels of accessibility to various transport modes (Reichert & Holz-Rau, 2015, p. 90).

For long-distance travel, a higher population **density** and a higher degree of **diversity** (mixed land use) around public transport stations make these modes more attractive (Limtanakool et al., 2006, p. 333). Cervero also found that higher densities and land-use mixtures lead to more transit riding and less drive-alone automobile travel (2002, p. 280). In general, public transport is more frequently used in high density areas than in lower ones. Interestingly, the larger the destination city, the higher the probability the train is chosen as mode of transport (Van Goeverden, 2009, p. 27). The size of the destination city is of greater importance than the size of the city of origin.

Proximity to transport **infrastructure** is related to density and diversity (Hollevoet et al., 2011, p. 133). Dargay and Clark state that there is no difference between living in an urban or rural area within Great Britain with regard to modal choice (2012, p. 585). However, Last and Manz, in a research on long-distance journeys, conclude the opposite: people living in rural areas rarely consider additional alternatives, probably because of the worse accessibility compared to urban areas and the interrelated usage of cars, leading to habitualness in mode choice (2003, p. 10).

Evidently, passengers in close proximity to HSR (less than 10 kilometres away) choose for rail more frequently (Garmendia, Ureña & Coronado, 2011, p. 549). The availability of a public transport stop increases the use of public transport (where the proximity of the stop at the destination side is of greater importance than the stop at the origin side; Limtanakool et al., 2006, p. 333). The size of railway stations matters as well: intercity stations lead to more rail travel than smaller stations. Accessibility of an inter-urban rail station also increases the use of the train considerably (Reichert & Holz-Rau, 2015, p. 102). Nonetheless, these results must be taken with care, as the results can be part of a self-selection mechanism: individuals and households may self-select themselves into a neighbourhood close to certain infrastructure (for example, an airport, a railway station or a highway; Van Acker et al., 2010, p. 224).

It is clear that for longer **distances**, faster travel modes are preferred (De Witte et al., 2013, p. 335). The chance of using rail is highest between 600 and 900 kilometres and very low between 1400 and 1500 kilometres (Van Goeverden, 2009, p. 27). Koppelman and Sethi (2004) conclude that with distance, the likeliness of using the automobile decreases. Distance, travel time and travel cost are directly related: normally, the longer the distance, the longer the travel time and the higher the travel cost (De Witte et al., 2013, p. 335). Moreover, cross-border travel seems to be problematic for rail travel. The probability of choosing the train for an international trip is only 30% compared to the probability of choosing the train for a domestic trip (Van Goeverden, 2009, p. 27).

Journey determinants

Higher **frequencies** make journeys less unpredictable. However, based on the review analysis of De Witte et al. (2013), frequency of public transport is less often found significant compared to other determinants. Bel found that a higher flight frequency leads to less inter-urban rail journeys (1997, p. 51). Therefore, several studies on air-rail substitution explicitly state that a high frequency of rail is of importance for substitution from air to rail. Moreover, Johansson et al. argue that flexibility, which is closely related to frequency, is significant for mode choice (2006, p. 509).

The travel **purpose** is an important factor as it initiates every journey (Hollevoet et al., 2011, p. 135). Limtanakool et al. (2006) make a distinction between three different trip purposes: commute, business and leisure. For commute trips, rail is used more frequently than for business and leisure trips. Van Goeverden also finds that the train is used more frequently for business than for leisure purposes (2009, p. 37). Moreover, he argues that for tourists, purpose contributes only a little to the overall explanation of train use (Van Goeverden, 2009, p. 28). In a study on Italian HSR, Bergantino and Madio found that HSR is more frequently used when the trip purpose is business (2020, p. 2).

Information about the different modes available for a journey leads to a better modal choice. However, in general, people are not willing to spend too much time and effort on their modal choice decision (De Witte et al., 2013, p. 336). Moreover, as discussed earlier, habitualness leads to less information gathering (Verplanken et al., 1997).

Depending on the purpose of travel, **travel time** can be valued differently (De Witte et al., 2013, p. 335). Some studies even state that travel time is the most important factor determining modal choice (Givoni, 2005, p. 49; Dobruszkes, 2011). Travel time is found to be especially important for business trips (González-Savignat, 2004, p. 103). Bel (1997) found that for inter-urban travel, travel time is very significant: the longer the journey time by rail, the less rail demand. Obviously, for night trains, the significance of travel time is lower.

Travel time generally consists of two kinds: in-vehicle time (time spent in the main mode of transport of a journey) and out-of-vehicle time (time spent outside the main mode of transport), of which the latter includes waiting time and access and egress time (time spent travelling to and from the original transport mode; Cho, 2013, p. 25). People using public transport are particularly sensitive to out-of-vehicle time. Access and egress time is particularly important in studies on modal choice between HSR and air transport (Moyano, Moya-Gómez & Gutiérrez, 2018, p. 85). The less time taken from origin to destination, the higher the probability of choosing one mode over another. For example, Moyano et al. (2018) found that the first and last mile of HSR trips account for a high percentage of total travel time. However, HSR has a travel time advantage over the aircraft as rail stations are usually located in or near the city centre (Givoni & Banister, 2007, p. 102). The access and egress mode of transport is therefore another important aspect of air-rail substitution as it has a significant effect on out-of-vehicle time. Diverse studies have focussed on this topic (see for example Moyano et al., 2018).

Value of time (VOT), the relative value attached to travel time, is another important aspect of modal choice (Dijst et al., 2002, pp. 40-41). It is the consideration between a fast, but expensive mode and a slow, but cheap mode. Normally, the VOT is between 5 and 25 euros per hour. For example, if VOT is 25 euros, a traveller making a decision between a rail journey of six hours and an air journey of three hours will choose for the train as long as the train is 75 euros cheaper. What has to be borne in mind is that other determinants are not taken into account in this example (Dijst et al., 2002, p. 41) For example, someone with a higher income might value time at another rate than someone with a lower income. Moreover, Givoni found a large difference in value of travel time savings (VTTS), the value of travel time saved, between the leisure traveller (4.05 euros) and the business traveller (61.68 euros; 2005, p. 139).

Travel cost, together with travel time, is one of the most important determinants for travellers when deciding how to get from A to B (Cervero, 2002, p. 266). Only focussing on these two elements of modal choice is too short-sighted. However, early studies did not focus on many other determinants.

The popularity of the low-cost model trend of air transport has shown that a low travel cost attracts passengers (Delaplace & Dobruszkes, 2015, p. 73). In general, business travellers are less sensitive to price than leisure travellers (Ivaldi & Vibes, 2005, p. 18). Public transport use is sensitive to increases in public transport fares: the higher the costs, the more people are likely to drive alone (Cervero, 2002). However, the opposite is not completely true: studies show that few car drivers would use public transport if it were made cheaper (De Witte et al., 2013, p. 336). In contrast to the importance attached to travel cost by most studies, Román et al. state that HSR demand is inelastic to price on the Madrid-Barcelona corridor (2009, p. 104).

Travel comfort is rather subjective, because it can be perceived differently by individuals (Givoni, 2005, p. 137). Johansson et al. found that although time and cost are still important, comfort is significant for mode choice (2006, p. 509). For long-distance travel, comfort plays a more important role than for short-distance travel, where aspects like travel time are more important (Vink, Bazley, Kamp & Blok, 2012, p. 354). However, comfort has many aspects and to date, few literature exists on travel comfort in relation to modal choice.

Interchanges (transfers) influence demand for a certain mode through the effect it has on both in and out-of-vehicle time and inconvenience and risks involved (Wardman & Hine, 2000, p. 4). Wardman and Hine state that a quick and easy interchange is essential if public transport wants to compete successfully with the convenience of the car. However, it is common for public transport trips and generally seen as something to be avoided (Hine & Scott, 2000, p. 223). In general, air travel requires fewer interchanges than rail. However, according to De Witte et al., it is among the less important determinants (2013, p. 337).

Modal choice can be influenced by the number of people travelling together. According to Van Goeverden, for train use, the most important determinant is the number of **participants in the journey** (2009, p. 27). Compared to a solo traveller, travelling with more than one person reduces the probability of travelling by train by 60%. The presence of children increases the utility of car use and therefore has a negative impact on public transport use (Limtanakool et al., 2006, p. 333).

2.1.2 Decision making

Modal choice includes both objective and subjective determinants (De Witte et al., 2013, p. 329). The level of importance attached to each of the discussed determinants differs from person to person as every person makes a decision on modal choice in a different way. Notwithstanding, it will differ from researcher to researcher: transport engineers might state that travel time and cost are the most important aspects of modal choice, while psychologists might refer to attitudes, norms and values (Last & Manz, 2003, p. 6).

Ettema distinguishes three different kinds of decision-makers who make their modal choice based on different implications and purposes: *homo economicus*, *homo psychologicus* and *homo obediens* (D. Ettema, personal communication, 15 November 2021). Homo economicus makes a rational decision to derive the highest utility possible, applying the *random utility theory*, which means that the alternative with the highest expected value is chosen (for example, fastest travel time and lowest travel cost). Homo psychologicus acknowledges people make decisions based on other theories as well. Three psychological theories explain how homo psychologicus makes decisions: the *theory of planned behaviour* (Ajzen, 1991), *norm activation model* (Schwartz, 1977) and *habit formation* (Verplanken et al., 1997). The theory of planned behaviour implies that intention is a central factor to actually perform certain behaviour. Intention is influenced by the attitude towards the behaviour, subjective norm (normative beliefs) and perceived behavioural control (availability of resources and opportunities). The norm activation model implies that personal norms lead to action in case of awareness and responsibility. The habit formation theory argues that habit is a repeated choice: it is scripted in long-term memory and prevents the overload of information processing. A change in behaviour requires a break of habit, but the stronger the habit, the less likely a change in behaviour. The behaviour of homo obediens can be changed by rules or laws. The acceptability of the rules and laws depends on different factors, for example involved costs, effectiveness and problem awareness (D. Ettema, personal communication, 15 November 2021; see section 2.3.2).

2.2 Modes of transport

Modes of transport can be grouped into three broad categories, based on the medium they exploit: air, land and water (Rodrigue, Comtois & Slack, 2009, p. 127). Within the EU, the car is used most frequently for passenger transport, which accounts for 71.6% of modal split (figure 3). However, as this research focuses on air-rail substitution, this paragraph will focus on air and rail transport exclusively.

MODAL SPLIT

%

	PASSENGER CARS	P2W	BUS & COACH	RAILWAY	TRAM & METRO	AIR	SEA
1995	73.0	2.4	10.4	6.9	1.4	5.3	0.6
2000	73.2	2.0	9.9	6.8	1.4	6.3	0.5
2005	73.2	2.2	9.5	6.5	1.4	6.9	0.4
2010	73.5	2.1	8.9	6.6	1.5	7.0	0.4
2011	72.8	2.2	9.0	6.7	1.5	7.5	0.4
2012	72.8	2.1	8.9	6.8	1.5	7.5	0.3
2013	72.9	2.1	8.8	6.8	1.5	7.4	0.4
2014	72.9	2.1	8.6	6.8	1.5	7.7	0.4
2015	72.7	2.1	8.7	6.8	1.4	8.0	0.3
2016	72.5	2.0	8.6	6.7	1.4	8.5	0.4
2017	72.3	1.9	8.1	6.8	1.4	9.1	0.3
2018	71.9	1.8	8.1	6.8	1.5	9.6	0.4
2019	71.6	1.9	8.1	7.0	1.4	9.7	0.3

NB: **Air and Sea**: only domestic and intra-EU-27 transport; estimates for air and for sea based on Eurostat data. The time series for maritime activity from 1995 to 2004 and for aviation activity from 1995 to 2007 have been recalibrated by DG MOVE in line with the new EU-27 figures to avoid break in series. Following change in the methodology, time series on maritime activity was revised.
P2W: Powered two-wheelers.

Figure 3: Modal split of EU-27 (EC, 2021c, p. 48)

2.2.1 Air

Air travel is the only sector within the EU to have gained significant terrain with regard to modal split (figure 3). Between 1995 and 2019, the modal share of air has almost doubled, whereas the modal share of rail has almost stayed the same (despite the widespread introduction of HSR). Moreover, between 1991 and 2010, the number of flights within the EU increased by 60% (Dobruszkes, 2011, p. 873).

Partly responsible for the rapid growth of air transport is the rise of the low-cost airline (LCA), of which Ryanair and EasyJet are famous examples (Rothengatter, 2010, pp. 320-321). LCAs were introduced in 1991 for the first time and grew rapidly by the late 1990s. In 2010, 31 LCAs were registered in Europe, with a total market share of about one third of the air transport market. *Legacy carriers*, longer existing airliners like KLM and British Airways, have lost ground to these low-cost carriers (Adler, Pels & Nash, 2010, p. 812). A number of carriers were therefore on the verge of bankruptcy or entered alliance agreements or mergers to ensure their long-run existence.

Figure 4 illustrates the wideness of the air network within the EU. Since 1991, the number of links has increased by 80%. It is however a delicate manner to compare rail with air travel supply (Dobruszkes, 2011, pp. 872-873). Air services usually consist of direct flights from A to B without stopovers, while rail travel serves a series of places (A-B-C-D). Therefore, distances covered by rail are more efficient geographically, linking more places than is possible over the same distances by air. However, at the same time, travel by plane is much more direct.

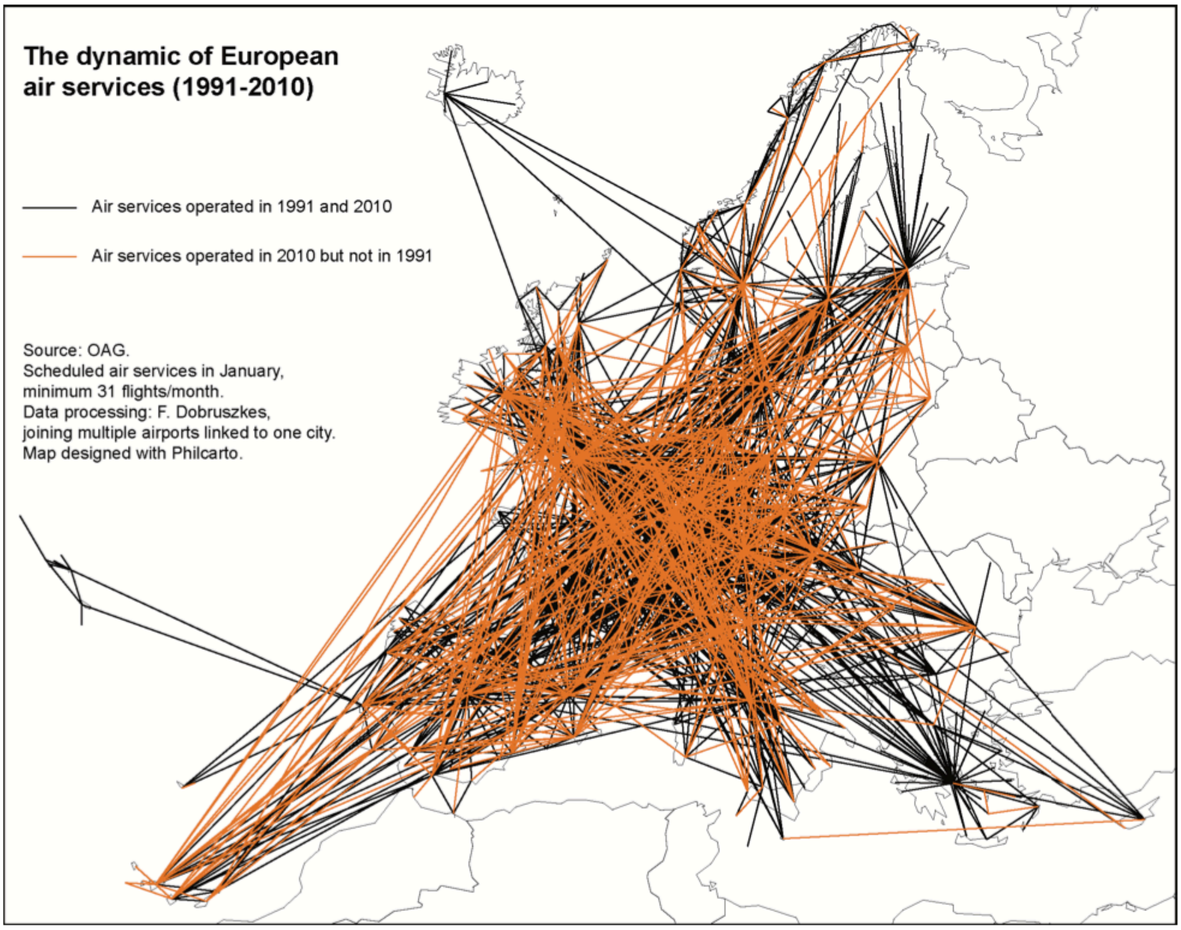
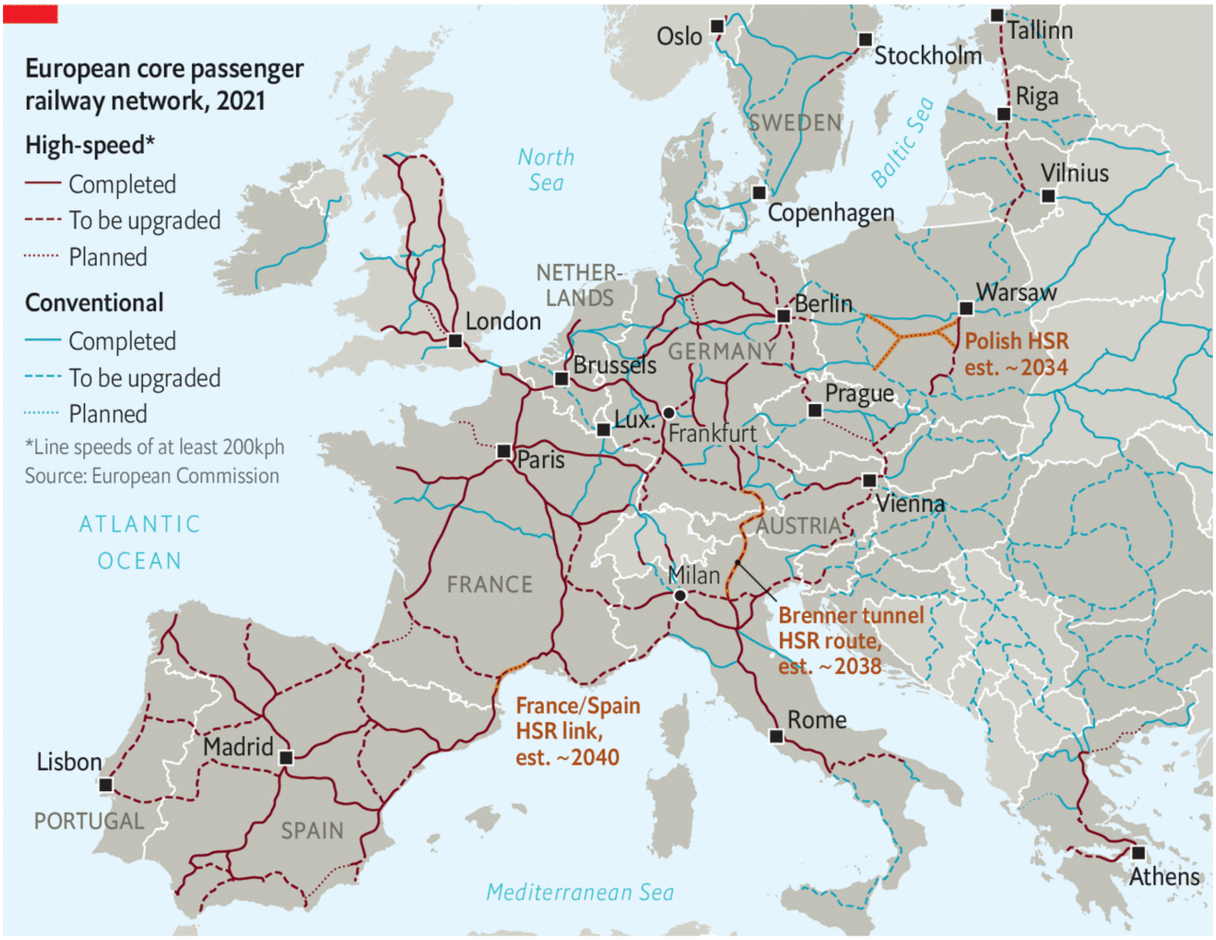


Figure 4: long-standing and new air routes. Comparative sketch of Europe's air network in 2010 (Dobruszkes, 2011, p. 873)

2.2.2 Rail

Rail consists of both conventional railways, allowing for an average speed (approximately 140 km/h) and high-speed railways, allowing for higher speeds (approximately 200 km/h or more). For air-rail substitution, especially the HSR network is of importance, as high-speed trains can be highly competitive with air (Behrens & Pels, 2012, p. 278). Since 1985, the HSR network within the EU has increased – as it has been subsidized heavily – from 599 kilometres to 11,526 kilometres in length (figure 5). Moreover, between 2001 and 2019, the number of HSR trains increased by 95% (EC, 2021d, p. 7). Simultaneously, the division of HSR kilometres within the EU is not equally distributed: Spain, France and Germany together accommodate 68% of all European HSR kilometres (EC, 2021c, p. 81).



The Economist

Figure 5: the European HSR network is still under development (The Economist)

One of the reasons why HSR is subsidized by the EU and, simultaneously, one way to achieve the 90% reduction-goal of the Sustainable & Smart Mobility Strategy is the *Trans-European Transport Network* (*TEN-T*; EC, 2021a, p. 8). TEN-T is an already longer existing policy which ‘aims at building an effective, EU-wide and multimodal transport network across the EU’ (EC, 2021e, p. 2). It consists of railways, waterways, roads, ports, airports and terminals. Most importantly, it ‘incentivises the sustainable and more efficient transportation of people and goods’ (EC, 2021e, p. 2). Although the policy comprises all modes of transport, the railway network is its backbone, as rail is considered a ‘more sustainable transport mode’ (EC, 2021e, p. 1). Milestones for the completion of TEN-T are therefore focused on rail. When completed, TEN-T will cut travel times between cities. It is worthwhile upgrading TEN-T if the authorities are interested in encouraging travellers to move from air to rail transport (Adler et al., 2010).

As figure 3 shows, rail transport, in contrast to air, has not seen an increase in modal split, despite TEN-T policy and the increase in length of HSR kilometres. HSR services almost doubled, but the total number of long-distance cross-border train pairs almost stayed the same between 2001 and 2019, partly due to the rapid decrease of night trains (EC, 2021d, pp. 6-7). Moreover, there are a number of obstacles (so-called *missing links*) to long-distance cross-border rail which are responsible for the absence of growth in international trains. The main problem of the European rail network is that it simply does not exist: obstacles range from missing infrastructure links to a missing single ticketing system (EC, 2021d, pp. x-xii; for more information, see EC, 2021d).

Another reason why rail lacks behind air travel is that rail transport has largely been excluded from the low-cost model trend of air transport (Delaplace & Dobruszkes, 2015, p. 73). This is due to the importance of infrastructure charges in the costs of rail operations (especially on HSR lines; EC, 2021d, p. viii). Before LCTs were introduced in rail transport, Ivaldi and Vibes estimated the effects of the introduction of LCTs on the German market (2005, pp.17-18). Surprisingly, they calculated that LCTs would affect airlines more than the existing services of Deutsche Bahn (DB, Germany’s biggest railway company), showing a market potential for air-rail substitution.

However, recently, rail companies have copied the low-cost business strategy of airlines with considerable success. Former discount HSR services, of which the first one (iDTGV) was introduced in 2004, failed. Now, notably Flixtrain in Germany (the company operating Flixbus) and OUIGO in France, the national train company’s (SNCF) low-cost train (LCT), are competing with LCAs (figure 6). HSR services tend to be rather expensive and therefore LCTs are more accessible to everyone (Delaplace & Dobruszkes, 2015, p. 73). While maintaining low travel costs, LCT journeys generally have a higher travel time (due to the mixed use of conventional lines and the HSR network) and a lower level of comfort. Moreover, within France, almost only peripheral stations are being served and there is a mandatory 30-minute check-in time: as a result, for the passenger, out-of-vehicle time is most likely higher.

Figure 6: OUIGO, SNCF’s low-cost train (D. Gubler)

What can be concluded is that the EC has put a lot of effort in increasing the supply of rail transport in Europe. Since December 2020, the European market for the provision of long-distance rail passenger services has opened for competition (Ramos, 2020, p. 341). This has resulted in some LCTs like OUIGO entering the market. As the number of night trains has dropped dramatically, new night trains have recently been added, with more to follow (EC, 2021d, p. 7; Groen, 2022). A benefit of the night train is the ability to save an overnight stay at the destination, which can make it cost- and time-attractive. Moreover, the European Commission proposed an action plan in December 2021 to boost long-distance and cross-border rail services.

2.2.3 Air and rail markets

Whether LCAs have fostered competition with HSR is subject to debate (Delaplace & Dobruszkes, 2015, p. 73). Both for the LCA and LCT, the target audience is the leisure traveller (Delaplace & Dobruszkes, 2015, p. 78). LCAs grew explosively between 1998 and 2003. The success story of the LCA is the low-cost business strategy (Rothengatter, 2010, p. 321). According to Rothengatter, as a result, losses of rail were substantial, with the main reasons reduced travel time and lower fares (travel cost) of LCAs. Friebel and Niffka found that in Germany, the introduction of LCAs have led to a decrease of 50% in rail traffic volume (2009, p. 196). However, Behrens and Pels conclude that the LCA has a lower impact on passenger numbers of rail than conventional airliners for the business segment, while for leisure the opposite is true (2012, p. 287).

Market distortions foster competitive advantages for air transport (table 1; Rothengatter, 2010, pp. 332-334). A bottleneck for infrastructure investment for railways is its associated high sunk development costs (Rothengatter, 2010, pp. 335-336). Because of the duration and complexity of legal processes involved with land acquisition, uncertainty about costs are high, with very often cost overruns as a result. Moreover, on the demand side, the expected passenger volume is often not achieved and it may take a decade before full performance is reached, with very often overestimations of demand. Therefore, rail infrastructure investments are generally planned and financed by the state. This is in contrast to air transport, which has low sunk costs (Rothengatter, 2010, p. 340). Air transport can adjust to changed demand more flexibly than rail. Regional airports are often subsidized, while successful airports are even able to finance extensions by their own (Rothengatter, 2010, p. 336). Moreover, HSR needs a high occupancy rate to become as cost efficient as air. Most importantly, the EU has been rather 'schizophrenic' in terms of air transport versus the environment (Dobruszkes & Givoni, 2013, p. 192). International air transport, in contrast to rail transport, is still free of fuel and energy taxation, although there are plans to tax fuel (EC, 2021b, p. 3). In other words, air transport is under-taxed, which creates relative price distortions, particularly compared to rail transport (Krenek & Schratzenstaller, 2016, p. 15). According to Rothengatter (2010), subsidisation of air transport should be stopped completely and fully integrated in the EU Emissions Trading System (ETS), which charges energy consumers (of which air is a large consumer).

Moreover, Rothengatter states that to achieve a fair modal competition between air and rail, the best option is a railway reform towards a fully commercialised railway network, operating internationally on an interoperable network (2010, p. 341). Behrens and Pels also recognize the threat of non-competition in rail transport and state that, in contrast to air transport, most HSR routes are currently operated by a single consortium (2012, p. 287). This is why the EC has opened up the international train market for competition in December 2020 (Ramos, 2020, p. 341). However, effects of this may be rather limited due to the still persistent missing links (see section 2.2.2; EC, 2021d, p. 1). On the London-Paris route for example, different airliners (both LCAs and legacy carriers) compete with each other, while the rail service is still only operated by Eurostar.

Air	**Rail**
Many low-cost carriers (LCCs)	Few LCCs
Low sunk costs (often self-financed)	High sunk costs (often state-financed)
Flexible towards demand	Not flexible towards demand
Energy not taxed	Energy taxed
Fully commercialised	Not fully commercialised[1]

Table 1: comparison of market characteristics of both modes of transport

[1] Commercialised in December 2020, but long-standing companies still dominate the market

2.3 Air-rail substitution

Up until the early 1990s, air and rail transport were seen as completely different and independent from each other (Adler et al., 2010, p. 813). Earlier, the role of railways was to provide access to airports, which meant that rail fulfilled a complementary role for air instead of substituting it (Givoni & Banister, 2007, p. 95). However, modal competition, the competition between different modes of transport for the same passengers, nowadays attracts more and more attention in the literature (Behrens & Pels, 2012, p. 286). Air-rail substitution specifically has gained attention too as investments in HSR lead to rail increasingly competing with air on long-distance journeys (Dobruszkes & Givoni, 2013, p. 193). This section focusses on air-rail substitution explicitly. First, the potential for air-rail substitution is explained. Second, modal shift is discussed. Third, an overview of existing studies on air-rail substitution is presented.

2.3.1 Potential

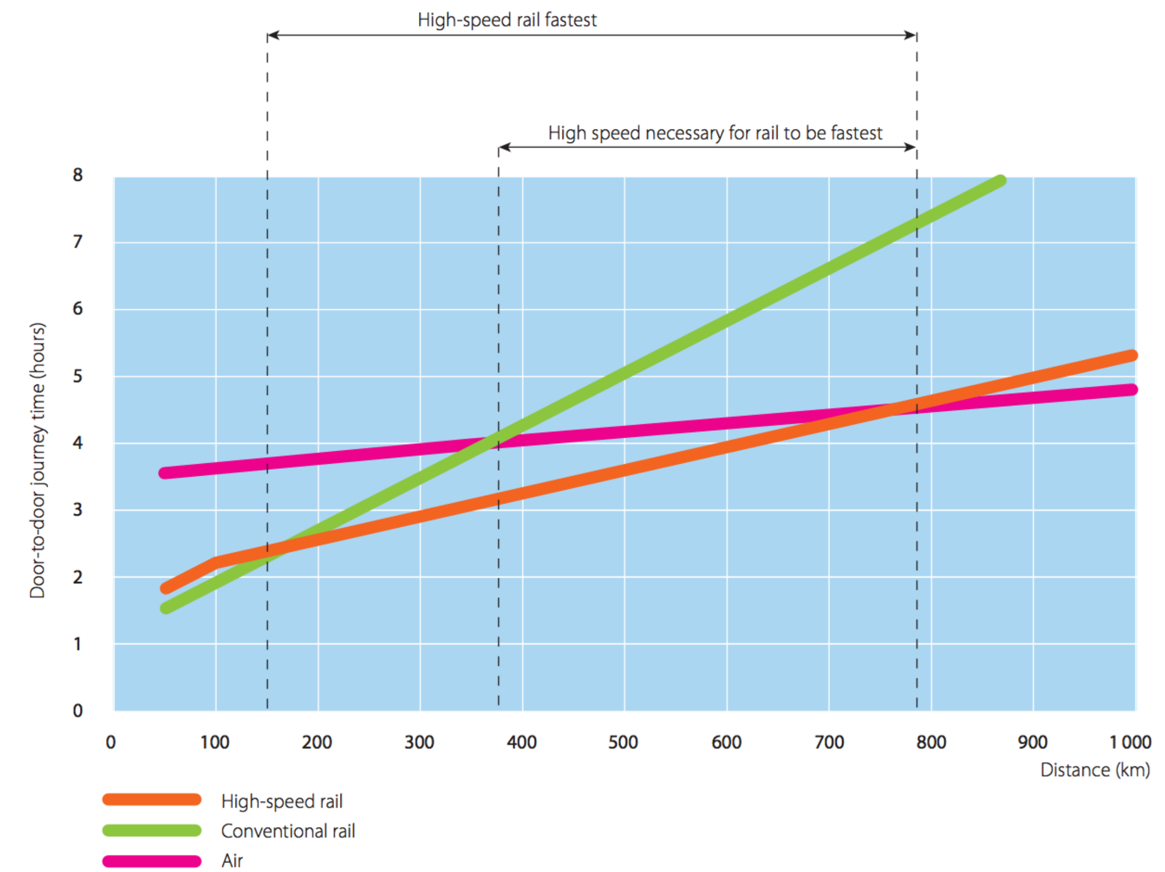


Figure 7: door-to-door journey time for HSR, conventional rail and air (EC, 2010, p. 11)

The potential for air-rail substitution lies between a range of 400 to 800 kilometres (figure 7; Rothengatter, 2010, p. 319). Above 800 kilometres, air transport has bigger advantages than rail: the modal share of rail fades away, although there are some exceptions (Savelberg & De Lange, 2018, p. 2). Below 400 kilometres, road transport is the main competitor of rail. Other studies mention slightly different distances, for example 600 to 900 kilometres (Van Goeverden, 2009, p. 27). Moreover, some studies measure the potential for air-rail substitution in time instead of distance in kilometres. Kroes and Savelberg found that HSR dominates the market for rail journeys of two hours or less, while claiming only a small amount of market share of rail journeys longer than five to six hours (2019, p. 170). González-Savignat states that HSR is competing with air on a distance covered in a maximum of three hours (2004, p.

103). However, the overall consensus in the literature is a maximum distance threshold of 800 kilometres.

Givoni (2007) makes a critical note on the assumption that air-rail substitution is beneficial for the environment. He states that introduction of HSR often results in airlines increasing their service frequency in order to protect their market share (Givoni, 2007, p. 227). If an aircraft seat is substituted for an HSR seat however, environmental benefits from mode substitution are expected. Rothengatter also states that the environmental advantage of rail over air diminishes if occupancy rates of the train are low (2010, p. 319). Moreover, Dobruszkes and Givoni even argue that a low load factor can lead to HSR being more pollutant than the plane (2013, p. 178). D'Alfonso, Jiang and Bracaglia also argue that the net environmental effects of HSR can be negative due to additional demand: there is a trade-off between the *substitution effect* – how many passengers shift from air to rail – and the *traffic generation effect* – how much new demand is generated (2016, p. 262). So, air-rail substitution has environmental benefits only if rail services have a high traffic density and load factors are met. It must be noted however that the environmental benefits derived from air-rail substitution also strongly depend on how the energy is generated (Givoni, 2007, p. 226). In the Netherlands for example, all trains of Nederlandse Spoorwegen (NS, the biggest Dutch railway company) run on green (wind) energy, making even empty trains environmentally friendlier than planes (Nederlandse Spoorwegen [NS], n.d.).

2.3.2 Modal shift

For air-rail substitution to take place, a change in modal choice is needed, which is a modal shift. However, habit is a very strong determinant of modal choice (see section 2.1; Gärling & Fujii, 2009, p. 104). If an individual is used to travel by a certain mode of transport, chances are low the individual will change his or her mode easily. Last and Manz, in their research on mode alternatives, found that for only 13% of all potential journeys, respondents consider alternative trips (2003, pp. 4-5). For business, this is more (18%) than for leisure purposes (11%). They explain the lack of considering mode alternatives due to habitualness. Moreover, young and well educated people show the highest potential for mode change (Last & Manz, 2003, p. 10).

One way of trying to change travel behaviour is by means of travel demand measures (TDMs; figure 8). TDMs focus on changing or reducing demand of a specific mode of transport (Gärling & Fujii, 2009, p. 97). However, TDMs are not common in long-distance travel, as TDMs typically focus on short distances, such as the commute trip, and the car as mode of transport. A distinction of travel behaviour modification is made between structural methods (changing travel options: journey characteristics) and psychological methods (changing beliefs, attitudes and values: socio-psychological characteristics; Gärling & Fujii, 2009, p. 106; De Witte et al., 2013, p. 332). Two types of structural methods exist: push measures and pull measures (Gärling & Fujii, 2009, p. 98). Push measures make a chosen mode relatively less attractive (for example, a flight tax), while pull measures make alternative modes relatively more attractive (for example, a reduction of train fares). Although both measures are effective to change travel behaviour, push measures generally have a negative public attitude and pull measures typically face budget constraints. Psychological methods are typically 'methods of words', i.e. communication measures (Gärling & Fujii, 2009, p. 108).

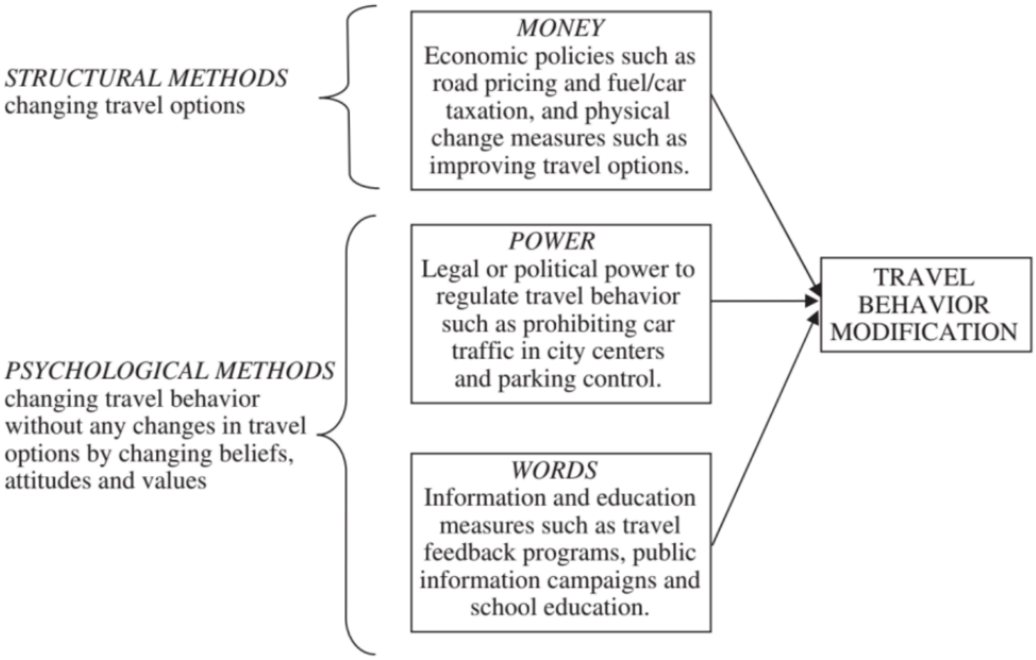


Figure 8: overview of structural and psychological methods as TDMs (Gärling & Fujii, 2009, p. 106)

For air-rail substitution, although not common, TDMs can trigger a modal shift by travellers too. The first instrument, money, can be – applied to air-rail substitution – either incentivizing rail or taxing air travel. However, in general, people respond more favourably and are more motivated when rewarded instead of punished (Geller, 1989). Moreover, Gärling and Fujii (2009) argue that a monetary pay off only leads to a temporary change in travel behaviour.

Tol (2007) investigated the impact of a carbon tax on aviation for international tourists. Even if a kerosene tax would be very high, emissions would drop by only a limited amount, as the cost of flying would rise by only a limited amount (Tol, 2007, p. 138). Especially short-haul flights would be affected, respectively because of high take-off and landing emissions. If a tax would be applied to the EU (which will be likely to happen in the future; EC, 2021b, p. 3), tourists would stay closer to home and European tourism would grow. Most importantly, train holidays would increase.

Wit and Dings (2002) conclude that a flight tax of €50 per tonne Co_2 (€3 to €5 per person per trip) would reduce emissions by 4.9%, but this is almost entirely due to a reduction in travel demand – not modal shift. Krenek and Schratzenstaller calculated the increase in flight prices for different tax scenarios (2016, p. 24). They found that a €25 tax per tonne carbon emissions would lead to an increase of 3.5% on ticket prices, while a €35 tax per tonne would lead to an increase of 5%. Overall, passenger numbers in the EU would drop by 4% if aviation would be taxed by €35 per tonne carbon emissions. For Germany, Ivaldi and Vibes found that a kerosene tax of 65 cents per litre leads to an increase of 10% on ticket prices (2005, p. 18). Eventually, this leads to a loss in passenger numbers of 7 to 18% for LCAs and 20 to 35% for the German national legacy carrier, Lufthansa.

Besides taxing air travel, rail travel can be incentivized in order to make a modal shift happen. For value added tax (VAT), if it were reduced from 16 to 7% in Germany (which eventually happened in 2020), Ivaldi and Vibes found that the rail market share would increase significantly, especially for the leisure market (2005, p. 19). Particularly, a shift from LCAs to rail would take place.

The second instrument, power, refers to physical power (barriers) and political power (regulation; Gärling & Fujii, 2006, p. 107). It is not expected to be used for long-distance travel very soon. Prohibiting certain travel behaviour is limiting someone's freedom, which triggers resistance. Moreover, Eriksson et al. (2006) found that fairness and freedom are most important when implementing TDMs.

The third instrument, words, contains information measures such as travel feedback programs (TFPs). TFPs are 'forms of personalised communication aimed at changing travel behaviour' (Fujii & Taniguchi, 2006, p. 339). Fujii and Taniguchi (2006) reviewed ten TFPs in Japan and concluded that TFPs are effective soft measures for promoting travel behaviour change, also for Western countries.

2.3.3 Determinants

Existing studies on modal competition between air and rail mainly focus on one or more specific corridors, which leads to problems with generalizability of the results. Therefore, table 2 presents an overview of recent studies on air-rail substitution with the main determinants for each corridor outlined.

Behrens and Pels found for the London-Paris passenger market that frequency, total travel time and distance are main determinants (2012, pp. 286-287). Interestingly, they found that a longer average travel time for HSR can be compensated by frequency and fares to attract passengers. Moreover, it is found that modal competition in this market segment depends heavily on trip purpose, as the train mainly competes with LCAs for leisure purposes and with conventional airliners for business purposes.

Savelberg and De Lange (2018) and Kroes and Savelberg (2019) investigated the feasibility of air-rail substitution for short-distance air travel at Amsterdam Airport and its 13 most important destinations. They predict that by 2030, a minimum of 1.9 million and a maximum of 3.7 million air journeys can be replaced by train annually (in other words, HSR could lead to a reduction of 2.5% to 5% of all flights to and from Amsterdam Airport). Both a reduced travel time of HSR and lower ticket prices of rail were found to be the most important determinants. Besides, higher frequencies and increased comfort could 'seduce' passengers to substitute air for rail. They distinguish four main determinants, which are – in order of importance – travel time, frequency, travel cost and comfort.

Donners, Van Buuren and Rijniers (2018) estimated the change in modal split for a reduction in travel time of rail travel between Amsterdam Airport and 31 destinations. They found that rail passenger numbers for all 31 destinations can be doubled. Moreover, with some simple measures, flight movements from Amsterdam Airport can be reduced by 18%. If the European HSR network is further integrated, the reduction would be 27% and the total number of rail passengers 2.5 times the number it is now.

Dobruszkes focused on five city pairs (Paris-Metz, Paris-Brussels, Brussels-London, Paris-Marseilles and Cologne-Munich) and found that travel time is an important factor if HSR is to compete successfully with air travel (2011, p. 878). If HSR travel time is lower compared to air, HSR is able to 'cannibalise' virtually all airline markets (Dobruszkes & Givoni, 2013, p. 182). Besides, additional variables such as frequencies, fares and the geographical structure of a region (density and diversity) are important.

Román et al. (2009) conducted research in a Spanish context on the Madrid-Zaragoza-Barcelona corridor, on which a new HSR was opened. People who used HSR were more women than men, slightly older and had a slightly higher income than plane users. Important determinants were found to be (the interaction of) travel time with travel purpose and comfort. For this research, Román et al. made use of revealed preference (RP) and stated preference

(SP) databases as well as willingness-to-pay (WTP). WTP for travel time savings was greater for mandatory trips (commute, business) than for other trip purposes (leisure). A higher WTP was found for delay time for the train than for the plane. Moreover, WTP was found to be high for more comfort of air travel. Román et al. (2009) concluded that HSR had a low level of competition over air transport services on the Madrid-Barcelona corridor, showing that policy makers had been too optimistic about figures of modal shift from air to rail.

Before HSR was introduced on the Madrid-Barcelona corridor, González-Savignat (2004) studied the potential of HSR replacing air services on the corridor, using SP and WTP. She found that WTP is higher for travel time savings, but lower for access time savings (higher however for plane users) and improvement in frequency (González-Savignat, 2004, p. 101). Price levels and travel times of the new alternative would affect competition the most. The advantages of HSR would decrease dramatically if travel time increases, which is especially of importance for business trips. She concluded that HSR was expected to capture 40% of the market shares in the business sector and almost 60% in the leisure sector.

Bergantino and Madio (2020) conducted research on planned HSR services between Bari and Rome (450 kilometres) and Brindisi and Rome (570 kilometres), where train travel already ranks first and air second in terms of modal split. Using stated preference, they studied the propensity to change the preferred alternative given current choices towards the new HSR, focussing on socio-economic determinants. Bergantino and Madio found that with age, income and education, probability of shifting to the new service increased (2020, pp. 7-9). Especially for business purposes, travellers are willing to change to HSR. However, frequent travellers, attached to habits, are less willing to change to the new service.

Corridor	**Determinants**	**Source**
London - Paris	Frequency, travel time, travel cost, distance, travel purpose	Behrens & Pels (2012)
Amsterdam Airport - 13 destinations	Travel time, travel cost, frequency, comfort	Savelberg & De Lange (2018), Kroes & Savelberg (2019)
Amsterdam Airport - 31 destinations	Travel time	Donners et al. (2018)
5 city pairs	Travel time, frequency, travel cost, density and diversity	Dobruszkes (2011)
Madrid - Zaragoza - Barcelona	Travel time, travel purpose, comfort	Román et al. (2009)
Madrid - Barcelona	Travel time, travel cost	González-Savignat (2004)
Rome - Bari and Rome - Brindisi	Age, income, education, travel purpose	Bergantino & Madio (2020)[2]

Table 2: overview of existing literature on air-rail substitution

Following from table 2, the recurring most important determinants of air-rail substitution are, in order of importance, travel time and travel cost, which are both journey-related determinants. Slightly less important are frequency and travel purpose. Comfort is also an often-named determinant. What becomes clear is that socio-demographic, socio-psychological and spatial determinants seem to be less important determinants of air-rail substitution. Most studies focus on journey determinants.

[2] Research focusses on socio-economic determinants

2.4 Conceptual model

The conceptual model that can be devised from the theoretical framework, partly based on the framework of De Witte et al. (2013, p. 332), is shown in figure 9.

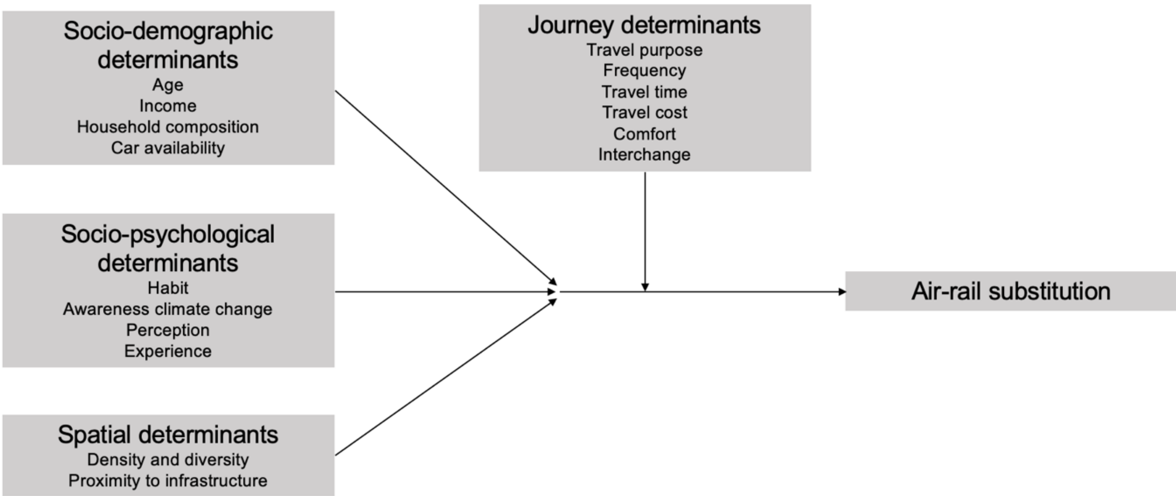


Figure 9: conceptual model (author)

3 Methods

This chapter presents an overview of the methods used to answer the central question: what are the most important determinants influencing air-rail substitution on long-distance journeys within Europe? First, the research design is discussed. Second, the operationalisation and data analysis follow. Third, reliability and validity is described. Fourth and last, the response is discussed briefly.

3.1 Research approach

The determinants of air-rail substitution are researched quantitatively, because an important part of the research methods is based on decision-making, for which a quantitative approach is suitable. Moreover, a large sample can be attained using a quantitative approach, which makes the outcome of decision-making and therefore the results more reliable. A disadvantage however of the chosen quantitative methods is the underexposure of the reason behind certain choices individuals make.

An online survey made by use of Qualtrics has been developed, which has been distributed via social media (for the survey, see appendix F). An online survey has some important advantages: data analysis is fast, as all response is already digital, *routing* can be controlled and respondents are easily reached, which makes it a suitable approach for this research, as time is short and means are lacking (Scheepers, Tobi & Boeije, 2016, pp. 163-164). Moreover, an online survey is easy to fill out for the respondent: it can be taken at the respondent's own pace, whenever and wherever wanted. A disadvantage of an online survey is the respondent's ability to quit the survey at any time (Scheepers et al., 2016, p. 182).

With regard to the four determinants, socio-demographic, socio-psychological and spatial determinants are operationalized by means of questions or statements (see section 3.2). Journey determinants are operationalized by means of stated preference (SP), using a discrete choice experiment (DCE). DCE is a quantitative technique used for eliciting preferences if revealed preference data is absent (Weber, 2021, pp. 903). Stated-preference approaches are especially useful for transportation research to quantify mode choice preferences. It allows the researcher to test hypothetical situations, which makes it a suitable approach for this research: different attribute levels within the DCE in this research are hypothetical. However, a disadvantage is that stated preference may differ from choices made in reality (revealed preference).

The survey is built up as follows. First, basic socio-demographic survey questions are asked: these are important to obtain, as socio-demographic characteristics are also part of the conceptual model (see figure 9). Spatial determinants are covered by the respondent's postal code and asked in the beginning of the survey as well. Next, part of the questions related to socio-psychological determinants (habit and experience) are asked. The SP questions need some thought to answer and therefore are the most 'difficult' part of the survey, positioned in the middle. After the SP questions, some last statements on awareness of climate change and perceptions (socio-psychological determinants) are positioned. The last statements are highly subjective and therefore positioned at the end, as they would possibly influence the respondent's SPs if they had been asked before the SP questions.

The survey is set up in such a way that questions in the beginning are easy to answer, in the middle more difficult to answer and towards the end easier to answer again. This order, being logical and positioning the most difficult questions in the middle of the survey, proves to be an efficient research design at the respondent's convenience, increasing the chance the respondent will finish the survey (Scheepers et al., 2016, p. 169).

The final version of the survey turned out to be rather long with 27 SP questions. Therefore, the survey has been split into two separate surveys (including either 13 or 14 SP questions) in order to shorten the survey, as a long survey would higher the chance respondents quit before finishing. In essence, two similar surveys were distributed, but with different choice sets within the DCE. Therefore, each respondent filled out one of the two surveys. Moreover, after testing the survey, which was first intended to be in English only, the survey language turned out to be too difficult for Dutch respondents. Therefore, the survey is translated to Dutch as well. With regard to ethics, the survey is fully anonymous. Questions which are probably sensitive for the respondent to answer (for example, income) are fit with an opt-out answer category ('prefer not to say'). All confidential data of the respondent is only collected for comparison of results.

The research area consists of two areas: the region of Zuid-Limburg and the city of Utrecht, both in the Netherlands (see appendix A). The reason for choosing these two research areas is two-folded. On one hand, the author can reach respondents easily within his area of residence (Zuid-Limburg) and the city where the author studies (Utrecht), ensuring a fair number of respondents in the amount of time available. On the other hand, comparison between both research groups based on geographical and socio-demographical differences is possible: both research groups differ in place of residence (predominantly rural versus urban) and age (various ages versus mostly students). However, it is not unimaginable the survey will also be filled out by respondents living outside both areas, as there will be made use of a snowball sample. Because the respondent's postal code is asked, which allows for geographical comparison, this will not be an issue for data analysis.

The research units are therefore in essence all inhabitants of the Netherlands (although two specific research areas are chosen) who have made an international trip by either plane or train (more than 400 kilometres in length) at least once between 2015 and 2020. In 2019, before the COVID-19 pandemic, 75% of Dutch citizens went on a holiday abroad and almost half of Dutch citizens took a flight at least once that year (CBS, 2019). Therefore, it is assumed that a large majority of respondents have made a cross-border long-distance trip (and a modal choice therefore) at least once between 2015 and 2020.

Respondents were chosen non-representatively, because the time and means were lacking to attain a representative sample, as the research units form a very large group (Scheepers et al., 2016, pp. 176-177). Both a convenience sample and snowball sample were used as sampling methods. These sampling methods have the advantage that data collection is fast and sufficient. However, both sampling methods have clear implications for the data analysis and generalisability (see section 3.3.1).

3.2 Operationalisation and data analysis

Five constructs can be devised from the conceptual model, which have different indicators and items (see figure 9). The operationalisation can schematically be found in appendix B.

Socio-demographic determinants form the first construct and follow from the basic questions asked in a survey (gender, age, place of residence, etc.). Following from the theoretical framework, age, income, household composition and car availability are important determinants of modal choice in general (see section 2.1.1 and Limtanakool et al., 2006) and air-rail substitution specifically (see Bergantino & Madio, 2020). In addition to the most important indicators following from the theory, gender, level of education and employment status are included in the survey as well, because they are regarded as basic survey questions. The (five) levels of education follow from Statistics Netherlands and are applicable to the Dutch school system to make the answer categories interpretable for respondents (CBS, n.d.). Indicators of socio-demographic determinants are straightforward and therefore only need one item each to cover them.

Indicators of socio-psychological determinants, the second construct, are habit, awareness of climate change, perception and experience (see Hollevoet et al., 2011). These four indicators are measured by different items. Habit is measured by subscription to a rail company and frequent flyer program, most frequently used mode on a daily basis and considering alternatives. Awareness of climate change is measured by five different statements regarding thoughts about climate change and actions taken. Perception is measured by perceived speed and price of both air and rail travel as these have proven to be important determinants of modal choice (De Witte et al., 2013, pp. 336-337). Experience is operationalised by asking the respondent how many times he or she has travelled internationally (more than 400 kilometres) by both plane and train. Both perception and awareness of climate change are measured by statements on a 5-point Likert scale (ranging from 1 (strongly negative) to 5 (strongly positive)), because a Likert score is a good way to indicate a respondent's attitude towards perception and awareness of climate change, both highly subjective indicators. Assumptions about perception and awareness of climate change will therefore be based on the Likert scores.

The third construct, spatial determinants, is less often included in long-distance modal choice studies (De Witte et al., 2013; Arbués et al., 2016, p. 133). Hence, only two indicators, density and diversity and proximity to infrastructure, are important according to the literature and therefore included (see table 2). Both are measured by the respondent's postal code, as this gives an objective view on the spatial characteristics of the respondent's place of residence.

Indicators of the fourth construct, journey determinants, follow from table 2 (an overview of air-rail substitution studies) as well. Moreover, an additional question is asked to put all journey determinants in order of importance in order to check the coherence between this question and the results of the DCE. The most frequently mentioned determinants are included: travel purpose, frequency, travel time, travel cost, comfort and interchange. Interchange is added only for rail travel, as this is a common feature of rail travel and less for air travel: both modes of transport differ strongly on this point. At the same time, it is seen as something to be avoided (Hine & Scott, 2000, p. 223).

Travel purpose is an important determinant of modal choice. However, travel purpose in the DCE is set to leisure, because not everyone travels for business purposes, while leisure purposes determine most international trips for Dutch inhabitants (CBS, 2019). Moreover, varying travel purposes within the SP design would probably create confusion amongst respondents. Different travel purposes require separate studies.

Frequency is the number of trains or planes per hour. The frequency levels of air are lower and of rail higher, as trains usually have a higher frequency than planes. Travel time of air is between 1 and 2 hours, while for rail, travel time ranges from 2 to 6 hours, as planes reach higher speeds. Moreover, the levels for travel time are set this way, because the potential for air-rail substitution lies between 400 and 800 kilometres (Rothengatter, 2010, p. 319). Travel time of air is further split into in-vehicle time and out-of-vehicle time, because airports (in contrast to railway stations) usually lay outside the city centre and therefore most of the time need to be reached by another mode of transport (Cho, 2013, p. 25). Moreover, for rail travel, an international journey can start at any station in the vicinity of the traveller (hence, interchanges) and therefore does not have a significant out-of-vehicle time. Levels of out-of-vehicle time are set between 2 and 4 hours, which closely match reality in which a traveller must be present at the airport a couple of hours before departure.

Travel cost is set by experiment, as different measures of the EU aim to either make air travel more expensive or make rail travel cheaper in the future. Therefore, prices of air travel are higher (ranging from €150 till €350), taking into account a potential flight tax of approximately €100. Rail travel prices are between €100 and €300 and therefore slightly cheaper than prices of air travel. Comfort is specified to the type of seat, on-board availability of Wi-Fi and on-board beverages. For rail travel, the level of comfort is exaggerated with a free meal, in order to test a hypothetical situation in which comfort of the train is high. Interchanges range from 0 to 2, which is most common for international rail journeys.

All journey determinants are used in the DCE. The levels are set arbitrarily and therefore include some hypothetical situations, because the international travel market is changing. However, all situations are not unimaginable and therefore closely resemble reality.

The fifth and last construct, air-rail substitution, is operationalised by the outcome of the DCE. The DCE consists of two alternatives: air travel and rail travel (see appendix C). Each alternative has five attributes and every attribute three levels (labelled 0, 1 or 2). In total, using the SPSS *Orthogonal design* function to create an uncorrelated design, 27 choice tasks are derived from all levels possible. Because the research has a general approach and is fully focussed on determinants, the choice tasks are not related to a specific corridor (for example, Amsterdam-London) for illustration purposes and are therefore without further conditions. Linking choice tests to different corridors would probably influence a respondent's SP by for example past experience with travelling on a specific corridor.

Data analysis is done in SPSS. An overview of all statistical tests applied can be found in appendix D. For descriptive statistics, standard statistics such as cross tabulations and figures are produced. Nine items are statements on a 5-point Likert scale: to test the internal consistency of the statements and therefore the reliability of the Likert scale, item-analysis is conducted. Moreover, for the DCE, binary logistic regression is used, because the dependent variable (air or rail) is a dichotomous variable (De Vocht, 2019, p. 181)[3]. The fit of the regression model on the data is further tested by a Hosmer-Lemeshow Test.

3.3 Reliability and validity

Most issues regarding reliability and validity of the research approach are already addressed in section 3.1. However, some aspects of this research need additional explanation.

3.3.1 Reliability

Both a convenience sample and a snowball sample have implications for the data analysis and generalisability of this research. Selectivity may occur, because the sample has been within reach and may have different characteristics from the group of people not surveyed (De Vocht, 2019, p. 195). Because the selection of respondents is not a-select, statistical testing and therefore making claims about the whole population is not possible. The results are exclusively applicable to the respondents of the survey of this research. Therefore, in the results chapter, there is referred to 'respondents' only.

A high reliability within the survey is aimed for by making use of answer categories: for example, a survey question related to income sometimes requires a very rough estimation for the respondent. By using answer categories, chances are high the respondent will give a reliable estimation of his or her personal situation. Except for age, postal code and two questions related to the indicator experience, which are based on an estimation of respondents, all questions have answer categories.

3.3.2 Validity

To achieve a high validity, the most important determinants influencing air-rail substitution following from the existing literature on modal choice and air-rail substitution more specifically are used for the operationalisation, as there is no existing measuring instrument available (see

[3] Only one model is produced, because Nagelkerke R Square (measure for the quality of the regression model) is sufficiently high

section 3.2). This way, the instrument to measure the most important determinants of air-rail substitution has been made as valid as possible.

At the end of the survey, a Likert scale is used for statements on perception and awareness of climate change. The use of a Likert scale has some important advantages. Validity of the instrument is high, because using more items, more aspects of a construct are measured (De Vocht, 2019, pp. 206-207). Reliability is high too, because item-analysis can be used to test if statements are internally consistent. Moreover, because a Likert scale consists of multiple items, a distinction between respondents can be made easily. The Likert scores can also be used for statistical calculations. However, there are some limitations of a Likert scale as well. Respondents tend to avoid the extremes ('strongly disagree' or 'strongly agree') and may answer sensitive questions in a socially desirable way (De Vocht, 2019, p. 207). Moreover, all statements have the same weight, while this may differ in practice. The total score is sometimes misleading, because different combinations of item-scores can lead to the same total score. By means of item-analysis, internal consistency of the statements and therefore the reliability of the Likert scale is tested.

3.4 Response

In total, 102 surveys were collected. 4 surveys were completely left blank: most certainly, they were opened and then closed immediately. Moreover, 19 respondents have left the SP questions blank, and their response is therefore not included in the data analysis. The valid response is therefore 79. Moreover, 46 respondents filled in 13 SP questions and 33 respondents 14 SP questions. In total, this leads to a total of 1060 choice sets within the DCE. Another 13 respondents have indicated that they have neither travelled by plane nor train internationally. However, these respondents are not excluded from the data analysis, because it is not necessarily needed to have made an international journey (as it concerns stated preference) and this would further reduce the sample.

Item non-response is tackled as much as possible beforehand by making questions compulsory to answer within the survey. However, some item non-response occurred with regard to the open answer categories. The questions related to how many times the respondent has travelled internationally by plane and train were left blank multiple times. Most likely, people who have not travelled by either plane or train a single time have left the text field blank. Missing values linked to these two questions were replaced by a value 0 (the total number of respondents who have neither travelled by plane nor train is therefore 13, as mentioned in the previous paragraph). Moreover, both choice sets 17 and 25 of the DCE have one missing value and within the regression model, 14 missing cases occur. Other missing values than mentioned do not occur.

It must be noted that one outlier occurs with regard to the number of times travelled by train between 2015 and 2020. One respondent has filled in a value 30 for this item. Because this number of train trips is possible, it is not removed from the dataset. As this respondent falls into the oldest age class, consisting of only 5 respondents in total, this may give a distorted image for train use of this age class.

Moreover, there are some non-traders (respondents who choose either air or rail for all choice sets and therefore do not make choices) in the data. In total, seven respondents have chosen the train and three respondents the plane at all times. Because the number of non-traders is relatively great and it is likely some people intrinsically prefer one mode of transport in all situations, non-traders are not removed. However, this may also give a distorted image, as the relative importance of either air or rail strongly increases if air or rail is chosen for every choice set.

4 Results

In this chapter, the results are presented. First, an outline of the respondent group will be given. Next, all four sub-questions (related to socio-demographic, socio-psychological, spatial and journey determinants) are discussed. Finally, the determinants contributing the most to air-rail substitution are presented. All relevant SPSS output related to this chapter can be found in appendix E.

4.1 Respondents

The age of respondents ranges between 16 and 80 years. The average is 33 years and the mode is 22 years, which occurs 17 times. The age distribution is skewed: 46% of all respondents is aged 23 or younger, 78% is aged 47 or younger (figure 10). To make comparison in the rest of this chapter easier, age is further distributed into three classes: young (16-30 years, 52 respondents), middle (31-60 years, 21 respondents) and old (61-80 years, 5 respondents). The gender distribution, in contrast to age, is more or less equal: 52% is male and 48% female.

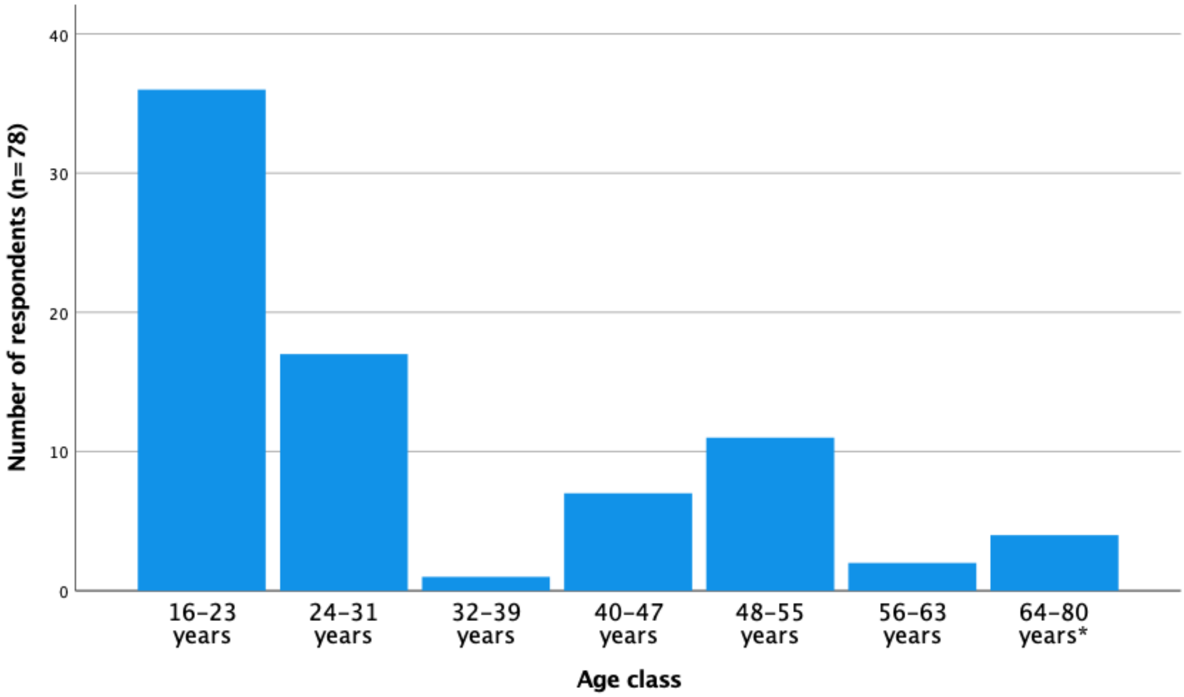


Figure 10: age distribution of 78 respondents (no respondents are aged between 64 and 71 years)*

Following a low average age, most respondents live together with their parent(s), with or without siblings (37%) or together with friend(s) or student(s) (19%; figure 11). Only 5% is a couple with 3 or more children, while the household class 'single with children' does not occur at all. Of all respondents, 60% lives in a household with children.

Most respondents (66%) have a *hbo* or university bachelor's degree as highest achieved level of education (level 4). Moreover, 25% of respondents has completed either secondary education or *mbo* as highest form of education (levels 2 and 3). 4% has only followed primary education (level 1) and 5% has achieved a university master's or doctor's degree (level 5).

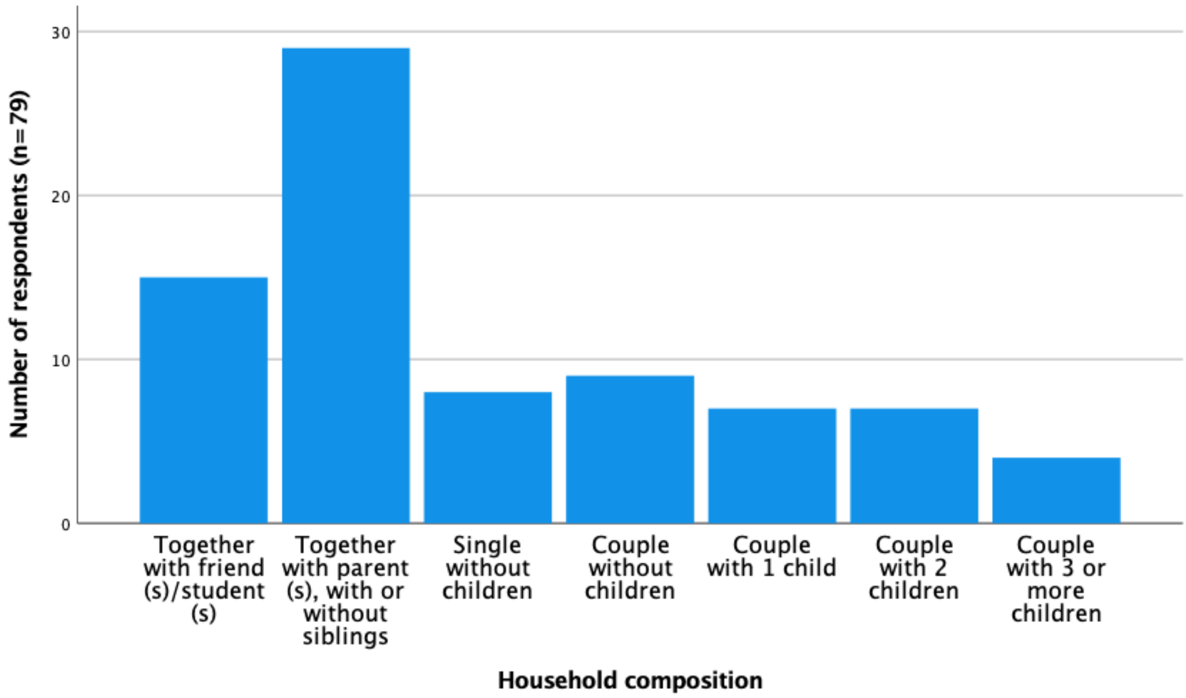


Figure 11: household composition of 79 respondents

Because the respondent group is young on average, 56% is school-going or student. 23% is full-time employed and 11% part-time employed, while 4% is self-employed and 6% retired or unable to work (figure 12). As more than half of all respondents has not entered the job market (yet), the majority of respondents (65%) falls into the lowest income class (earning €2000 or less). 15% earns between €2000 and €4000, while 10% earns €4000 or more. Another 10% prefers not to answer the income-related question.

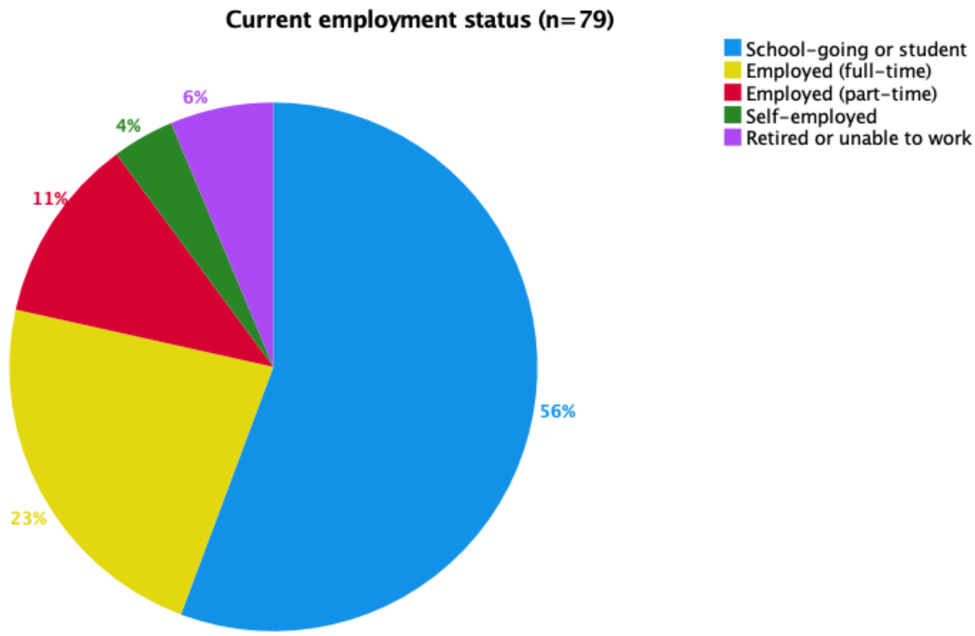


Figure 12: current employment status of 79 respondents

Respondents live in different areas throughout the country. The respondent's place of residence is split into three different categories: Zuid-Limburg, Utrecht and other. 42% of all respondents lives in Zuid-Limburg and 14% in the city of Utrecht (figure 13). The places of residence of the other respondents, which make up the largest group (44%), lie throughout the country. Nonetheless, these are individual respondents: no clusters of respondents in one particular place are present, apart from both research areas.

Respondents from Zuid-Limburg are with an average of 35 years slightly older than the overall average. As most respondents from Utrecht are students, the mean age is 23 years. The other respondents not living in either Zuid-Limburg or Utrecht have an average age of 33 years.

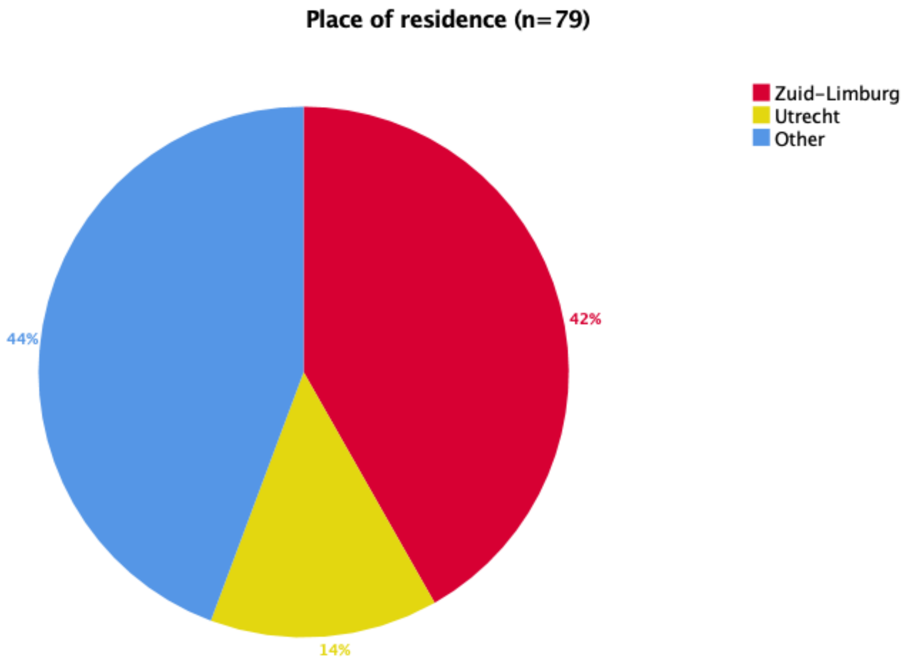


Figure 13: place of residence of 79 respondents

The place of residence of respondents is further split into urban and rural, based on the respondent's postal code. 43% lives in an urban environment, while 57% lives in a rural environment. The respondents living in an urban area are younger (average age 28 years) than the group of respondents living rural (average age 36 years).

Overall, the respondent group is considerably young, mostly living together with either their parent(s), with or without children, or with students or friends. Moreover, in general, respondents are higher educated, while a large part of the 79 respondents falls into the lowest income category (€2000 or less). Respondents live throughout the country, with two clusters (the original research areas, Zuid-Limburg and Utrecht).

4.2 Socio-demographic determinants

Following from the conceptual model, age, income, household composition and car availability are important socio-demographic determinants influencing modal choice and air-rail substitution (see figure 9). Age, income and household composition are already discussed in the previous section and are therefore not discussed here.

According to the literature, car availability has a very significant effect on mode choice for all purposes (Limtanakool et al., 2006, pp. 335-338). A majority of respondents, 79%, has a car to his or her availability. Therefore, it is not a surprise the majority of respondents with a car to his or her availability uses the car most often on a daily basis (table 3). However, train use is not higher among respondents that do not have availability of a car, albeit a relatively small group of respondents that do not have a car available (21%). Moreover, car availability is much higher if one or more children are present in a household (89%) compared to if there are no children present in a household (63%).

	Yes		No		Total	
	Count	%	Count	%	Count	%
Car	36	58	0	0	36	46
Scooter, moped or motorcycle	3	5	0	0	3	4
Train	7	11	2	12	9	11
Bus, tram or metro	1	2	0	0	1	1
Active mode (for example, walking or cycling)	15	24	15	88	30	38
Total	62	100	17	100	79	100

Table 3: most frequently used mode of transport on daily basis of 79 respondents with reference to car availability

4.3 Socio-psychological determinants

The second determinant group, socio-psychological determinants, consists of four indicators: habit, awareness of climate change, perception and experience.

Most respondents (63%) have a subscription to a rail company, against 37% who does not have a subscription (figure 14). Moreover, 78% of respondents who have a subscription own one that allows free travel at certain or all times. The other 22% has a subscription that allows discounted travel. Of the young age class, the majority (73%) has a subscription for free travel: this is probably due to the free rail subscription Dutch students are eligible for. Within both the middle and old age class, no respondents have such subscription. Moreover, 90% of the middle age class has no subscription to a rail company at all.

Fewer respondents, only 17 out of 79 (22%), are member of a frequent flyer program. Of the eight respondents with an income higher than €4000, five are member of a frequent flyer program: the large majority of respondents from the other income classes are not a member.

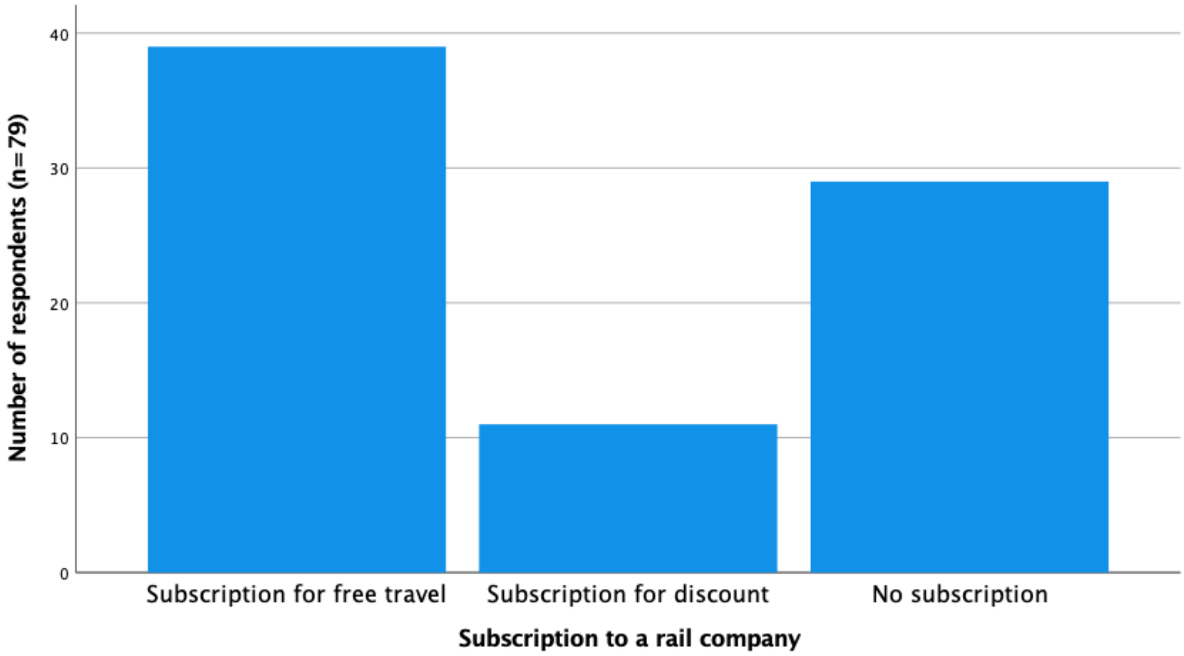


Figure 14: subscription to a rail company of 79 respondents

Although the amount of subscriptions is quite high among respondents, the car is the most frequently used mode of transport on a daily basis (46%), while an active mode (for example, walking or cycling) ranks second, accounting for 38% (figure 15). Only 10 respondents use public transport most frequently, of which 9 indicate they use the train most often.

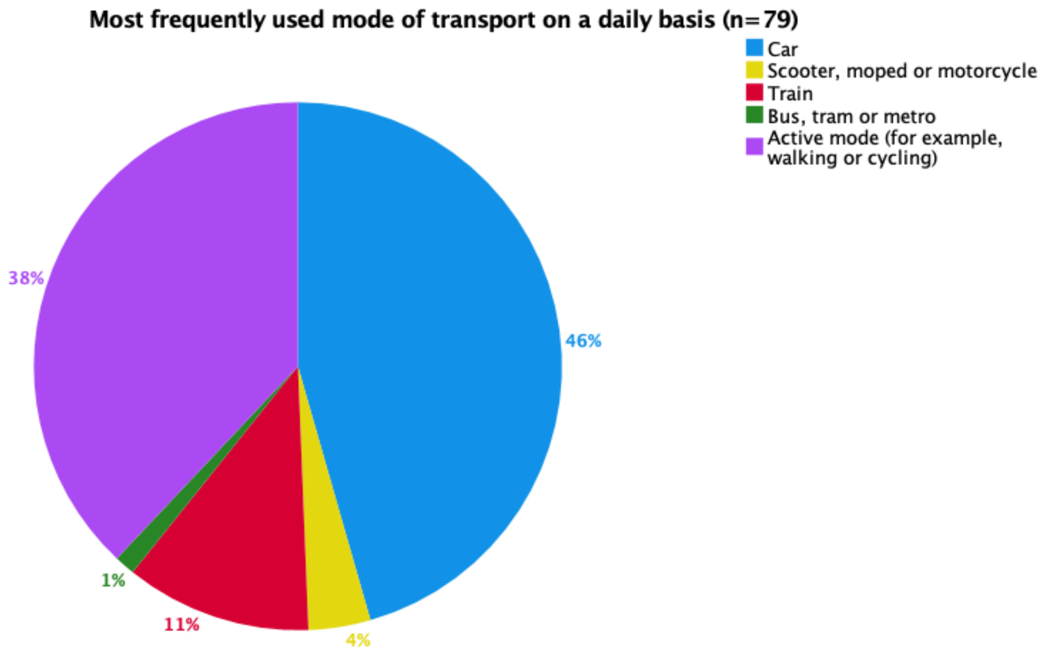


Figure 15: most frequently used mode of transport on a daily basis of 79 respondents

Households without children most frequently travel by foot, bike or another active mode (63%), while the car ranks second (16%) and the train third (13%). The car is obviously used much more in households with children (66%), while an active mode of transport ranks second and the train third with respectively 21% and 11%. Within the youngest age class, 42% of respondents walk, cycle or use another active mode of transport, while 35% indicates they use the car most frequently (figure 16). The middle age class uses the car most frequently (81%) and the oldest age class – like the youngest – an active mode of transport (80%).

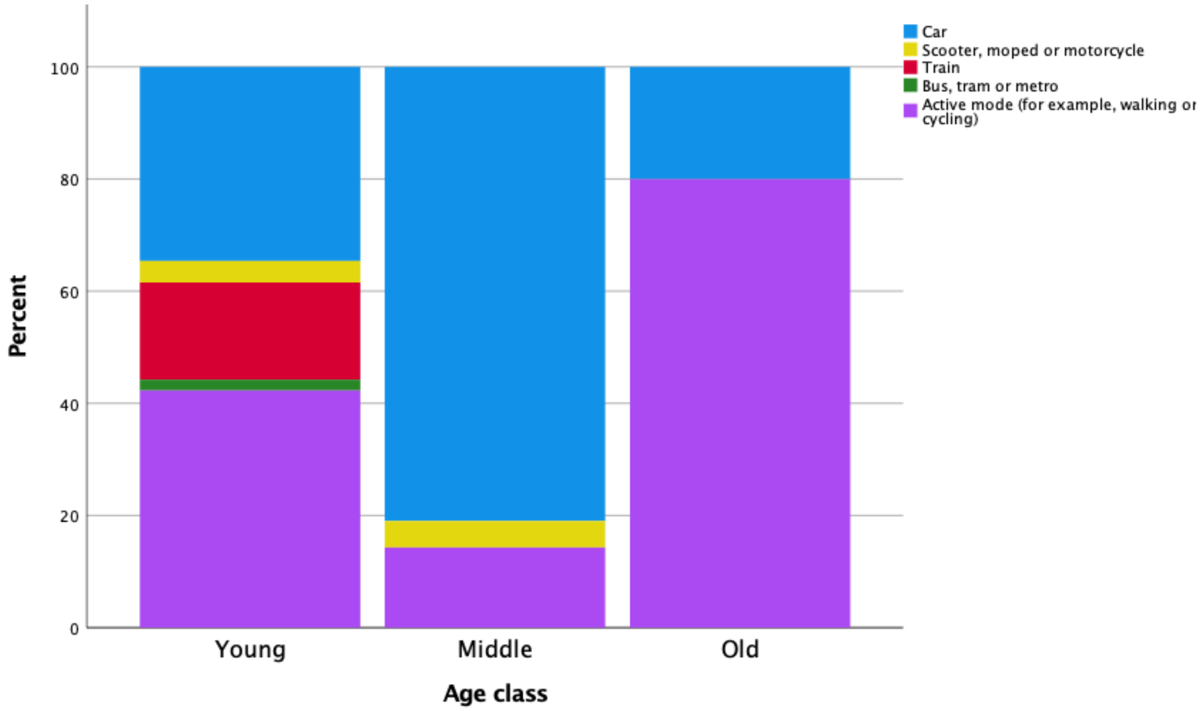


Figure 16: most frequently used mode of transport on a daily basis per age class of 79 respondents

With regard to the last international trip respondents have made, 7 out of 10 respondents indicate he or she did not consider an alternative mode of transport. In general, young people consider other alternatives more than older people: for example, within the youngest age class, 37% considered other alternatives when planning their last international trip, while this percentage drops for the older age classes. Moreover, households with children less frequently considered alternative modes of transport for their last international journey (23%) than households without children (41%).

In general, overall awareness of climate change and its consequences is high among respondents[4]. Almost all respondents (90%) are to a certain height aware of the fact that climate change is occurring, while 10% has a neutral stance towards it (figure 17). Worriedness about climate change is slightly less prominent among respondents than awareness, as 72% mentions to be worried about climate change. Another 14% indicates not to be worried about climate change. A majority of respondents takes action to mitigate climate change: 24% strongly agrees with the statement that they take action to mitigate climate change, while 42% somewhat agrees.

The young and middle age classes are in general more aware of climate change than the oldest age class, but the youngest age class is most worried about climate change. In contrast,

[4] The statements with regard to awareness of climate change are internally consistent (Cronbach's alpha = 0.762)

the oldest age class takes more action to mitigate climate change than the youngest age class. Theoretically educated respondents (with highest achieved level of education at least *hbo* or a university's bachelor, level 4) are on average much more aware of and worried about climate change than practically educated respondents (highest achieved level lower than *hbo* or a university's bachelor). They also more frequently take action to mitigate climate change. Moreover, there is a clear difference between respondents from urban and rural areas: respondents from urban areas more strongly agree with all statements with regard to climate change awareness than respondents from rural areas, with the biggest difference being the encounter of flight shame.

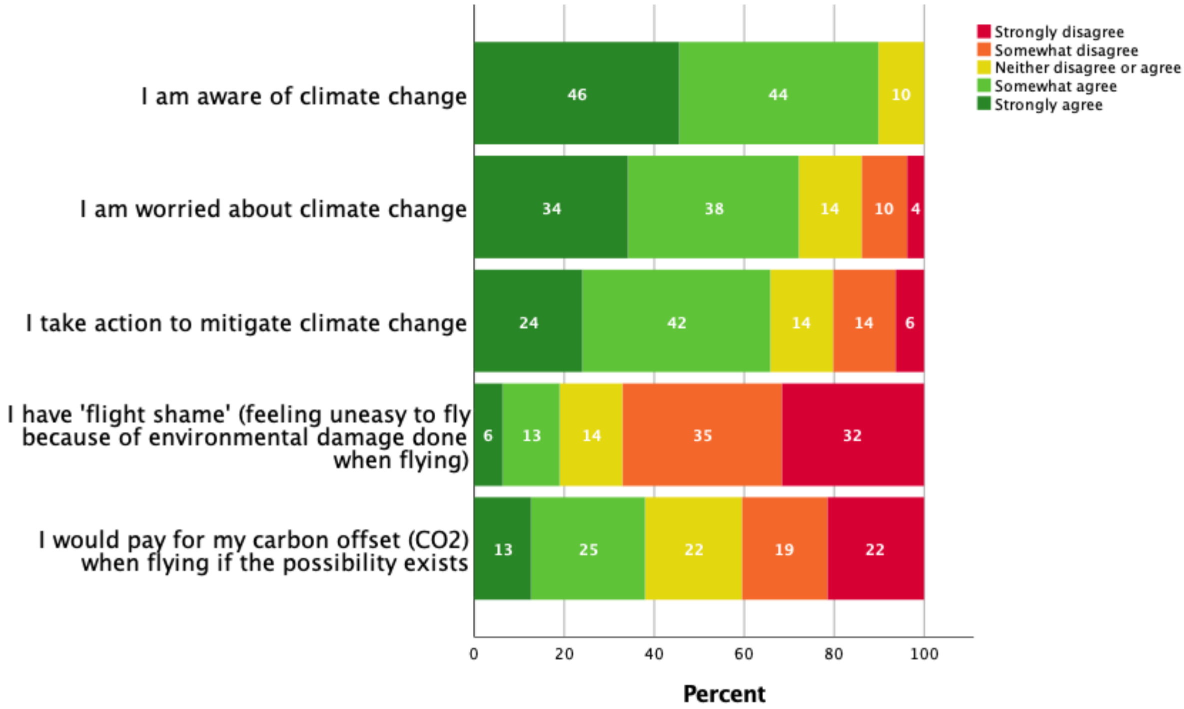


Figure 17: stance towards different statements on climate change awareness of 79 respondents

However, with regard to flying, of all respondents, only 19% encounters flight shame. As many as 32% strongly disagrees with the statement of encountering flight shame, another 35% somewhat disagrees. Although the feeling of flight shame is low, respondents are divided when it comes to paying for their carbon offset: 41% would most likely not pay for carbon offsets against 38% who most likely would. The middle age class is most likely to not encounter flight shame and pay for their carbon offset, which is not surprising, as they have flown the most between 2015 and 2020 of all age classes. Moreover, theoretically educated respondents more frequently encounter flight shame and pay for their carbon offset than practically educated respondents.

Rail transport is regarded as expensive among respondents[5]. 68% somewhat or strongly disagrees with the statement that travelling by train is cheap, against 15% that somewhat agrees (figure 18). Only 1 respondent strongly agrees with the statement. For air transport, travel price perception is more positive: 24% disagrees with the statement that travelling by plane is cheap against 49% who agrees that travelling by plane is cheap. The lowest income class (earning less than €2000 per month) perceives the plane as slightly cheaper and the

[5] The statements with regard to perception do not cover the construct 'perception' (Cronbach's alpha = 0.242). This means that perception is not measured, but the statements are regarded disjointed

train as slightly more expensive: 71% disagrees with the statement that travelling by train is cheap, 55% agrees that travelling by plane is cheap.

With regard to travel time of rail, 30% thinks travelling by train is fast, but more respondents (37%) believe that travelling by train is not fast. 34% has a neutral stance. It is not a surprise the middle age class (having flown most frequently) regards the train as most expensive and slowest of all age classes. However, they do not regard the plane as either cheaper or faster than other age classes. In general, for all respondents, travelling by plane is believed to be faster. As many as 73% thinks travelling by plane is fast, while 27% of all respondents disagrees that air transport is fast. So, respondents perceive air transport as both cheaper and faster than rail transport.

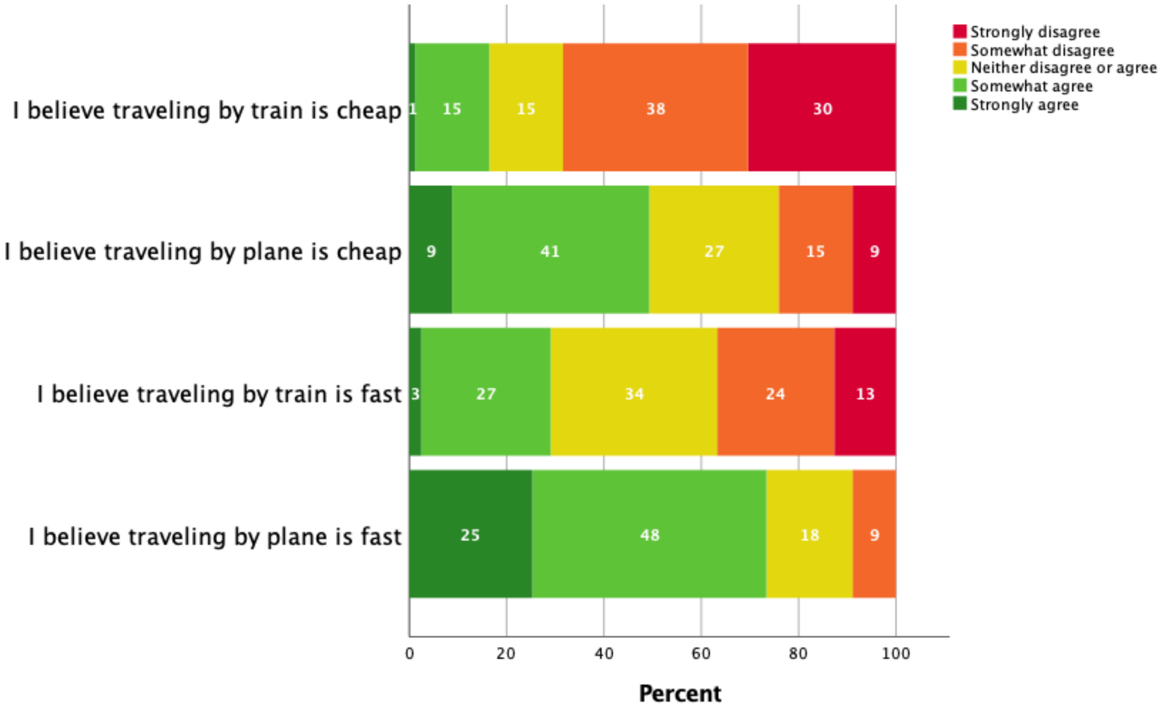


Figure 18: stance towards different statements on perception for 79 respondents

It is clear that most respondents take a flight more frequently than an international train. Respondents have taken an average of approximately 4.5 flights the last 5 years before the COVID-19 pandemic, while on average, only 2.4 trips were made by train. More than half of all respondents has not made an international journey by train in the last 5 years, while only 24% has not taken a flight in that period. Moreover, from the respondents that have made an international journey by train, 81% has made a maximum amount of 2 journeys. As mentioned earlier, the middle age class travelled most frequently by plane (average 5.2 trips) and least frequently by train (only 0.9 trips). The youngest age class ranks second in both average plane and train trips, while the oldest age class clearly travelled most by train (15.6 trips) and least by plane (2.6). However, the average trips made by train of the oldest age class relates to the outlier described in section 3.4.

Surprisingly, respondents who have a subscription to a rail company for free travel have used the train for international journeys in the last 5 years before the COVID-19 pandemic less than the average trips made by all respondents (table 4). Respondents who have a subscription to a rail company for discounted travel make the most international journeys by train (on average 7.5 trips) and much fewer plane trips (average 2.4 trips). However, it must be noted that this group is relatively small with just 11 respondents. Logically, the 17 respondents who are member of a frequent flyer program take the plane much more than average: the average plane trips for this group is 9.5. Surprisingly however, they also take the international train slightly more than average (2.7 trips in the last 5 years).

	Subscription for free travel	Subscription for discount	No subscription
Approximate trips by plane	4.7	2.4	5.1
Approximate trips by train	1.9	7.5	1.2

Table 4: average of approximate travel by plane and train the last 5 years before the COVID-19 pandemic (2015-2020) of 79 respondents with reference to subscription to a rail company

A lower income (€2000 or less) means slightly less trips by plane (4.3) and more trips by international train (3.3) than average, which is surprising given the negative stance towards perceived train cost of this group. Moreover, theoretically educated respondents travelled more by plane and less by train, while practically educated respondents travelled more by train and less by plane (figure 19).

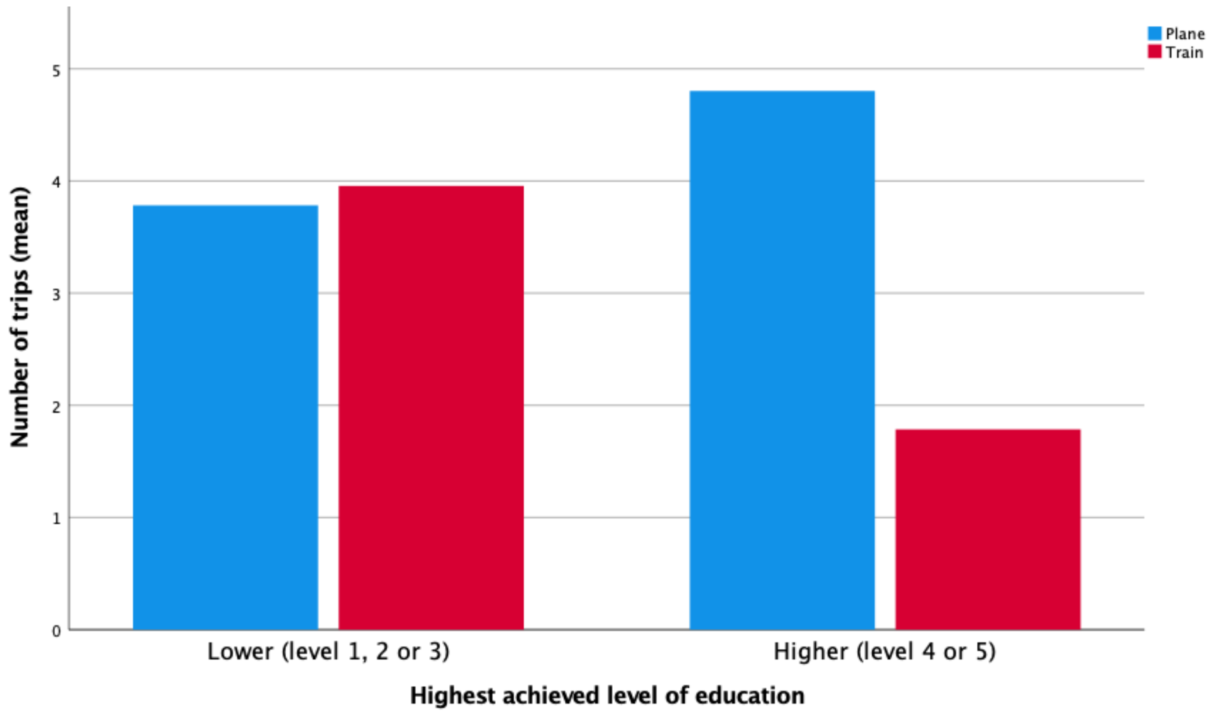


Figure 19: average number of trips by plane and train (the last five years before the COVID-19 pandemic) with reference to highest achieved level of education of 79 respondents

For households without children, train use is much higher (3.5 trips) than the average of 2.4 trips. Consequently, less trips are made by plane (4.1 trips). The opposite is true for households with children: they travelled slightly more by plane (4.8 trips) and slightly less by train (1.7 trips) on average between 2015 and 2020.

4.4 Spatial determinants

Respondents live in different parts of the Netherlands and therefore, they live in different spatial conditions with different characteristics in their (direct) surroundings (area of residence). According to the literature, both density and diversity and proximity to infrastructure are important indicators.

Urban areas generally have a higher density and diversity than rural areas. Last and Manz argue that people living in rural areas rarely consider alternatives because of reduced accessibility compared to urban areas and interrelated car use (2003, p. 10). In line with Last and Manz, car availability is much higher in rural areas, 89%, compared to 65% in urban areas. Moreover, respondents living in a rural area use the car most frequently (64%), while in an urban area, the majority of respondents walks or cycles (56%; table 5). Public transport is used more frequently by respondents living in urban areas (18%, of which 15% the train) than rural areas (9%, all train).

	Urban		Rural		Total	
	Count	%	Count	%	Count	%
Car	7	21	29	64	36	46
Scooter, moped or motorcycle	2	6	1	2	3	4
Train	5	15	4	9	9	11
Bus, tram or metro	1	3	0	0	1	1
Active mode (for example, walking or cycling)	19	56	11	24	30	38
Total	34	100[6]	45	100	79	100

Table 5: most frequently used mode of transport on a daily basis of 79 respondents with reference to area of residence

When looking at the number of trips made by plane and train, respondents from rural areas made more trips by both modes of transport (figure 20). There is a big difference between both areas in train use: respondents living in a rural area have made on average more than twice as many trips by train (3.2) than those living in an urban area (1.4). This is quite surprising, as the perception of both speed and price of plane and train are almost similar for both the urban and rural group of respondents.

[6] Partial percentages are rounded off to 0 decimals

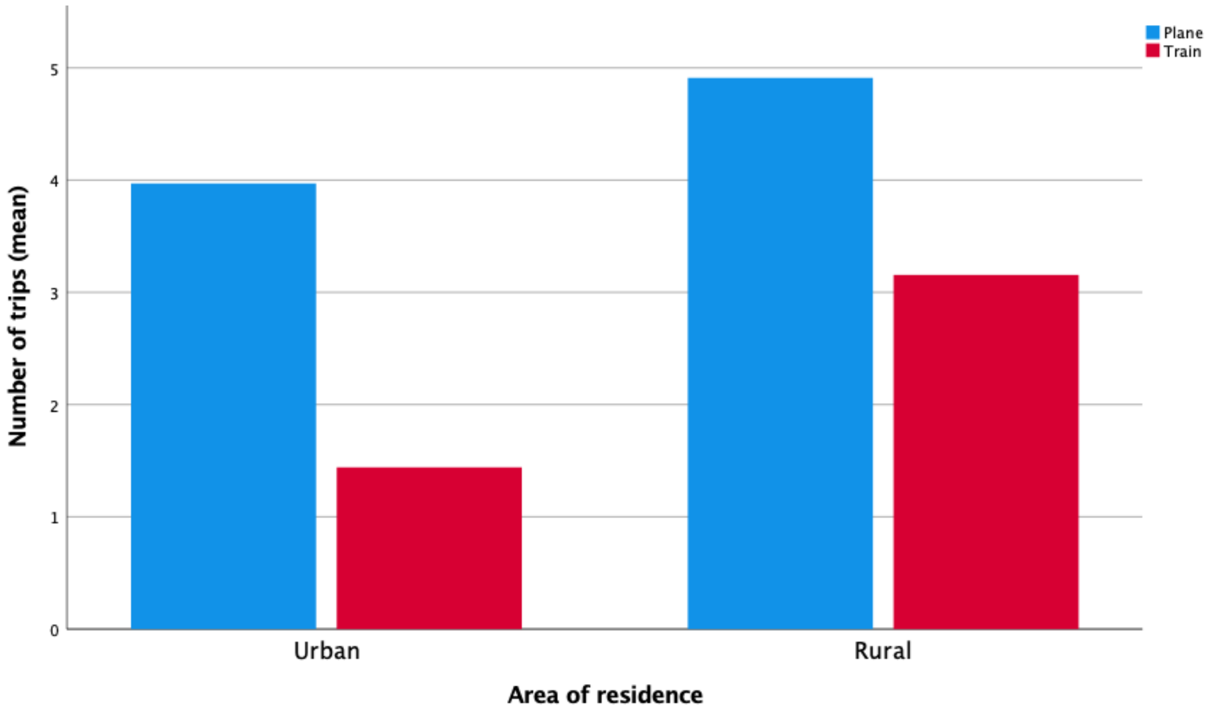


Figure 20: average number of trips by plane and train (the last five years before the COVID-19 pandemic) with reference to area of residence of 79 respondents

Proximity to infrastructure is another important aspect of air-rail substitution and closely related to density and diversity of an area (Hollevoet et al., 2011, p. 133). With regard to both research areas, respondents living in Utrecht live near a large international airport (Amsterdam Airport) and have a rail connection with Germany. Within half an hour, many international HSR connections from Amsterdam Central station are reached (see appendix A). Respondents from Zuid-Limburg have less direct international air and rail connections, although two large international airports and multiple stations with international rail connections are reached within an hour.

Although following from the literature (see for example Garmendia et al., 2011, p. 549), proximity to infrastructure increases the likelihood of long-distance travel (notably by train), respondents from Utrecht made less long-distance journeys in the five years before the COVID-19 pandemic. On average, they have made 3.6 trips by plane and 2.2 by train, while respondents from Zuid-Limburg have made 4.8 trips by plane and 3.5 by train.

4.5 Journey determinants

The construct journey determinants is the most diverse and consists of the indicators frequency, travel time (for air journeys further split into in-vehicle and out-of-vehicle time), travel cost, comfort and exclusively for rail journeys interchange.

Explicitly, respondents were asked – apart from the DCE – to put in order which journey determinants they regard as most and least important (table 6). Frequency is generally not seen as very important: 43% of respondents rank it as least important journey characteristic. Only 1 respondent sees frequency as most important journey characteristic.

	Frequency	In-vehicle travel time	Out-of-vehicle travel time	Travel cost	Comfort	Interchanges
Mode	6	2	4	1	5	5
Mean	5.0	2.8	3.7	2.2	3.8	3.6

Table 6: mode and mean of level of importance on a scale from 1 (most important) to 6 (least important) of six journey characteristics of 79 respondents

With regard to travel time, in-vehicle travel time is seen as more important than out-of-vehicle time. 82% ranks in-vehicle time as first, second or third most important journey characteristic, against 46% that ranks out-of-vehicle time first, second or third. 19% even regards out-of-vehicle time sixth, as least important journey characteristic. The most important journey determinant is travel cost: the majority ranks travel cost as most important (53%), while another 17% ranks travel cost as second most important journey characteristic. 4% ranks travel cost as least important.

Comfort is among the less important journey characteristics, although the value of importance attached to this journey characteristics varies among respondents: 10% ranks comfort as most important, which is the same percentage that regards it least important, while 56% ranks comfort as fourth or fifth. The value of importance of interchanges varies enormously and is almost perfectly distributed. 47% ranks interchanges first, second or third, against 53% which ranks it fourth, fifth or sixth in order of importance. Moreover, 18% sees interchanges as most important, another 18% as least important. On average, respondents regard travel cost as most important, followed by in-vehicle travel time, interchanges, out-of-vehicle travel time, comfort and frequency.

4.6 Air-rail substitution

Socio-demographic, socio-psychological, spatial and journey determinants influence air-rail substitution. However, the contribution of each determinant to the overall explanation of air-rail substitution varies. The importance of all determinants is described in more detail in this section.

From a logistic regression analysis follows that there is a significant effect of most determinants on the modal choice of 79 respondents of rail with reference to air. However, some determinants are not significant. The model declares 56% of the differences in modal choice and classifies 83% of the observations correctly, $\chi^2(60) = 619.57$, $p < 0.001$, Nagelkerke $R^2 = 0.60$[7]. See appendix E for the full SPSS output of the logistic regression model.

Significant socio-demographic determinants are age, household composition, level of education and employment status. Therefore, gender, income and car availability are not significant. However, income is related to level of education and employment status.

Age has a relatively low effect compared to other socio-demographic determinants. The older the respondent, the less chance the respondent will choose the train over the plane for a long-distance journey. All household compositions, except for a household consisting of a couple with 2 children, are significant. Moreover, all household compositions strongly reduce the chance to choose rail over air compared to the household category 'living together with friend(s) or student(s)'. The strongest reduction of the chance is when there are children present in a household. A couple with one child has the least chance to choose the train over

[7] Goodness-of-fit of the regression model is sufficient, $p > 0.05$ of the Hosmer-Lemeshow Test

the plane compared to living together with friend(s) or student(s). It is remarkable that a household with one child is significant, while a household with 2 children is not significant.

Except for the highest level of education (university master or doctor), all levels with regard to highest achieved level of education are significant. Compared to the lowest level of education (primary education), all higher levels reduce the chance of train use. The strongest reduction of the chance of train use is when a respondent’s highest achieved level of education is vmbo or mbo1 (level 2), compared to the lowest level of education. With regard to employment status, only being retired or unable to work is significant and has a clear effect. Being retired or unable to work strongly increases the chance to choose the train over the plane with reference to respondents who are school-going or student (however, this result relates to the outlier described in section 3.4).

Of all socio-demographic determinants, relatively, household composition is by far the most important determinant of air-rail substitution, followed by employment status and level of education. Age has the lowest importance.

With regard to socio-psychological determinants, multiple determinants are significant for air-rail substitution: subscription to a rail company, most frequently used transport mode on a daily basis, the consideration of alternative modes (items of habit), encountering flight shame (awareness of climate change), perception of price of the train and speed of the plane (perception) and the number of trips approximately made by train in the last five years before the COVID-19 pandemic (experience).

As expected, not holding a subscription to a rail company reduces the chance to use the train for long-distance journeys compared to a subscription for free travel. Moreover, holding a subscription for discounted travel also reduces the chance to use the train compared to a free travel subscription. The most frequently used mode of transport on a daily basis is also significant, except for the category ‘bus, tram or metro’. Compared to car use, all other modes strongly increase the chance of train use. Using the scooter, moped or motorcycle most frequently on a daily basis increases the chance of rail use most of all modes of transport. Furthermore, using the train most on a daily basis logically increases the chance of train use for long-distance trips as well. An active mode of transport also increases the chance of train use, albeit less than scooter, moped or motorcycle and train. Moreover, the chance of train use with reference to plane use becomes less when a respondent did not consider other modes of transport for their last long-distance journey compared to respondents who did. Habit is therefore a strong determinant of air-rail substitution.

With regard to climate change, logically, encountering flight shame strongly increases the chance of travel by rail compared to not encountering flight shame. However, other statements with regard to awareness of climate change are not significant. Surprisingly, if travelling by train is perceived as cheap, the chance of train use is lower compared to respondents perceiving the train as expensive. Evidently, respondents perceiving the plane as fast are less likely to use the train instead of the plane compared to respondents not perceiving the plane as fast. Moreover, as expected, for every additional trip made by train in the last five years before the COVID-19 pandemic, the chance of train use compared to plane use increases. Overall, awareness of climate change is less important, while perception is moderately important. Experience is important, as the number of train trips made is a strong determinant.

The most important determinant of all socio-psychological determinants is the number of trips made by train between 2015 and 2020 (experience), followed by most frequently used mode of transport on a daily basis and subscription to a rail company (habit). Relatively the least important contributors to the explanation of air-rail substitution are the consideration of other modes of transport for the last long-distance trip (habit) and perception of the speed of air transport (perception).

Spatial determinants, density and diversity and proximity to infrastructure, are significant for air-rail substitution. Although density and diversity are greater and proximity of infrastructure is better in urban areas, living in an urban area surprisingly reduces the chance of using rail transport for a long-distance journey compared to living in a rural area. This may seem surprising, but respondents from rural areas travelled more by both plane and train between 2015 and 2020 than respondents from urban areas. With reference to all other determinants, the contribution of both spatial determinants to the explanation of air-rail substitution is low.

Journey determinants are the most important determinants for air-rail substitution, which is in line with what was expected beforehand based on the literature. Almost all determinants are significant. Surprisingly, a lower frequency of air travel leads to less rail travel: the chance to use rail instead of air is much smaller if the frequency of the connection by air is lowest (6-hourly) compared to the highest frequency (2-hourly). A 4-hourly frequency by air also reduces the chance of rail use with respect to the highest frequency level, but the effect is much smaller. Apparently, respondents are not sensitive to a low frequency of air transport, but simultaneously, they regard it as very important.

Unlike out-of-vehicle time, in-vehicle time of air travel is significant, except for a travel time of 1.5 hours. An in-vehicle time of 2 hours increases the chance to travel by rail compared to a travel time of 1 hour. However, surprisingly, a higher travel cost of air is not a reason to choose for rail: for both higher travel cost categories (250 and 350 euros), the chance to use rail over air decreases with reference to the lowest travel cost level for air (150 euros). So, a higher air travel time is a reason for respondents to choose for rail, in contrast to a higher travel cost of air.

With regard to comfort, the highest comfort level of air (business class, free Wi-Fi and free drink and snack) reduces the chance to travel by train compared to the lowest comfort level of air (economy class). However, the middle comfort level (economy comfort class) increases the chance to use rail strongly compared to the lowest comfort level of air. Apparently, respondents are only sensitive to business class travel with some additional services like Wi-Fi and beverages compared to economy and economy comfort class.

The frequency of rail travel is, like the frequency of air travel, important for air-rail substitution, albeit less than for air travel. Surprisingly, the same effect as frequency of air travel occurs: the middle frequency level (2-hourly) strongly increases the chance to travel by rail compared to the highest frequency level (1-hourly). The lowest frequency level (3-hourly) is not significant. Like for air travel, respondents do not seem to be sensitive to frequency levels with regard to choosing for one mode over another.

Surprisingly, the highest travel time of rail (6 hours) is not significant. However, the middle travel time level (4.5 hours) is significant and reduces the chance of train use with reference to plane use, compared to the lowest travel time (3 hours). So, respondents are, for both modes of transport, likely to choose another mode if the travel time of that mode becomes longer. Moreover, respondents do not seem to be sensitive to a high travel cost of rail: the highest travel cost for rail (€300) increases the chance of travelling by rail instead of air compared to the lowest travel cost (€100). The middle price class is not significant with reference to the lowest price class.

Remarkably, the highest comfort level of rail (1st class, free Wi-Fi and a free meal) reduces the chance to use the train compared to the lowest comfort level (2nd class and free Wi-Fi). The middle comfort level of rail (2nd class, free Wi-Fi and a free meal) also reduces the chance of train use compared to plane use with reference to the lowest comfort level of rail, but slightly less. Therefore, respondents do not seem to be sensitive to a high level of comfort of rail, although they regard it as relatively important. Furthermore, only 0 or 1 interchange is significant. 1 interchange surprisingly increases the chance of using the train instead of the plane compared to no interchanges. Therefore, respondents do not seem to regard interchanges as a reason to choose the plane instead of the train.

The journey determinant most important to the explanation of air-rail substitution is frequency of air, closely followed by comfort of air. Comfort of rail ranks third, closely followed by frequency of rail. Relatively the lowest contribution to the explanation of air-rail substitution is the number of interchanges.

Of all determinants discussed in this chapter, frequency of air turns out to be the most important determinant influencing air-rail substitution, closely followed by comfort of air. Relatively, other determinants are less important. Of all significant determinants, the perception of the speed of air transport has the lowest importance.

5 Conclusion and discussion

Our climate is changing. Therefore, there is a need to act more sustainably, notable with regard to mobility. Air-rail substitution is highly beneficial for the environment and hence a way to reduce climate change. However, rail transport only forms a small part of modal share within the EU today. Therefore, this research examined the most important determinants influencing air-rail substitution in order to stimulate it. A survey was distributed in which respondents indicated their stated preference, by means of a discrete choice experiment, for either air or rail as mode of transport for different travel situations.

Determinants influencing air-rail substitution can be grouped into four categories: socio-demographic, socio-psychological, spatial and journey determinants. The most important socio-demographic determinant is household composition: the presence of children reduces the chance of train use instead of plane use. Relatively, the other significant socio-demographic determinants (age, level of education and employment status) are less important. The most important significant socio-psychological determinants are experience (the number of trips made by train, every additional trip increases the chance of rail use), followed by habit (the most frequently used mode of transport). All other modes than the car (except for the bus, tram and metro, which are not significant) strongly increase the chance of choosing rail over air. Spatial determinants, density and diversity and proximity to infrastructure are relatively less important. Living in a rural area increases the chance to choose rail over air compared to living in an urban area. Journey determinants are the most important determinants: frequency of air is the most important journey determinant, closely followed by comfort of air. Relatively, the other significant journey determinants are less important. Surprisingly, both travel cost and time of air and rail are, compared to other (journey) determinants, less important determinants influencing air-rail substitution, although respondents value the importance of both determinants high apart from the DCE. Moreover, what becomes clear is that the majority of journey determinants increase the chance of air use instead of rail use: apparently, respondents intrinsically prefer air transport over rail transport.

The answer to the central question, what are the most important determinants influencing air-rail substitution on long-distance journeys within Europe, can now be answered. Journey determinants, notably the frequency of air and the comfort of air, are the most important determinants influencing air-rail substitution on long-distance journeys within Europe.

The results are at some points contrary to what could be expected beforehand. For example, the effect of some socio-demographic determinants contradicts the literature. The literature does not show real consensus on the effect of age, while this study found a significant effect. However, this may be due to the young respondent group. The result for household composition however is in line with the literature: travelling with children reduces the chance of rail use (Hollevoet et al., 2011, p. 135). A higher level of education reduces the chance of train use, which is in line with multiple studies as well (for example Holz-Rau et al., 2014, p. 496). In contrast to Dargay and Clark's study, the youngest age class does not travel more by rail and less by air (2012, p. 585). For employment status, no clear effect was found in the literature and due to an outlier, no reliable statement can be made. Surprisingly, car availability is not significant, while previous research found that car availability is very significant for modal choice (Limtanakool et al., 2006, pp. 335-338). Hollevoet et al. even regard car availability as the most important determinant of modal choice (2011, p. 134). Moreover, income is not significant, while Reichert and Holz-Rau regard income as one the strongest determinants of modal choice (2015, p. 89).

With regard to socio-psychological determinants, habit is, as previous research has shown, an important determinant of air-rail substitution (see for example Bergantino and Madio, 2020). Three out of four items related to habit are significant. In line with Last and Manz, younger people consider other alternatives more frequently than older people (2003, p. 10). Although overall awareness of climate change is high among respondents, only one item related to awareness of climate change (encountering flight shame) is significant. Although the internal consistency is sufficient, the choice of items may be too straightforward. However, previous research also showed little support for the importance of environmental awareness on modal choice (Johansson et al., 2006, pp. 508-509). Perception on the other hand has two significant items and is therefore, in line with the literature, modestly important for modal choice (Hollevoet et al., 2011, p. 136). With regard to experience, the number of trips made by train is significant, while the literature did not show a clear effect of experience on modal choice.

The effect of both spatial determinants is in contrast to what was found in the literature. A higher density and diversity in general leads to more public transport use and more train use specifically (Limtanakool et al., 2006, p. 333; Van Goeverden, 2009, p. 27). Moreover, accessibility of an inter-urban rail station also increases the use of the train (Reichert & Holz-Rau, 2015, p. 102). Although daily public transport use is indeed higher in urban areas, the chance of rail use is higher for respondents living in a rural area, with a lower density and diversity and most likely reduced proximity to infrastructure. This also contradicts the study of Dargay and Clark, who found no difference between living urban or rural with regard to modal choice (2012, p. 585).

In contrast to the high level of importance found in this research, frequency is less often found significant compared to other determinants in the literature (De Witte et al., 2013). Notwithstanding, several studies on air-rail substitution explicitly state that a high frequency of rail is of importance for air-rail substitution. Both travel time and cost are, according to the literature, the most important determinants influencing air-rail substitution (Cervero, 2002, p. 266). However, this study found that time and cost are not the most important determinants: in fact, relatively, they are among the less influencing journey determinants. Out-of-vehicle time is not significant at all, while various studies focus on this topic and regard it as an important part of modal choice (for example Moyano et al., 2018). Perhaps, the difference between in-vehicle time and out-of-vehicle time has not been explained clear enough or is not important to respondents at all. Comfort on the other hand is very important, but hardly studied in the literature in relation to modal choice. The effect of the number of interchanges of a rail journey is in line with the literature: it is among the less important determinants (De Witte et al., 2013, p. 337).

What has become clear from this research is that travel time and cost are not as important as the literature suggests. Although the importance of both frequency and comfort of air is relatively the highest for the explanation of air-rail substitution, the effect of frequency (a lower frequency level of air leads to less chance of rail use) and comfort (a higher comfort level on the train reduces the chance of rail use) is surprising. However, it implicates that other journey determinants than travel time and cost are important influencers of air-rail substitution. Apart from journey determinants, household composition and experience are relatively important as well. Therefore, the importance of journey determinants appears to be overestimated and the importance of other determinants underestimated. Moreover, it has become clear that determinants related to long-distance journeys are different from the determinants of general modal choice and short-distance journeys, as the results differ from the existing literature on the topic.

For society, this research has shown that respondents are in general aware of climate change and following from this research, there is a need to move ourselves more sustainably, notably on long-distance journeys. This is possible by substitution of air by rail journeys. There are different determinants stimulating air-rail substitution, while other determinants are discouraging. Apparently, the trigger for travellers to choose for either rail or air is not only travel time and cost, but frequency and comfort as well. Moreover, travelling with children (household composition) and experience are important determinants which influence air-rail substitution as well: households with children apparently perceive rail transport as unpleasant, while experienced rail users on long-distance trips use rail more frequently as a consequence. In the end however, although travel behaviour can possibly be influenced by improving determinants of air-rail substitution, it is up to the traveller to choose for a more sustainable transport mode.

5.1 Reflection

The effect of most journey determinants is opposite to what can be expected beforehand based on the literature and on the ranking of journey determinants, in which on average frequency ranked lowest and travel cost highest in order of importance. According to the DCE, the opposite is true. Moreover, for example, a higher level of comfort of the train reduces the chance of rail travel, which seems to make little sense. Apparently, with regard to the DCE, respondents make other choices than what can be expected based on the literature and on the importance attached to journey determinants by respondents apart from their SPs.

Although it is hard to point out an exact explanation, as there are no issues regarding the regression model[8], a possible explanation regards the data. Clearly, a constraint of this research is the data collection. Therefore, the results should be interpreted with care as they only apply to the sample of 79 respondents, because respondents were chosen non-representatively. The respondent group is young on average and the majority lives in either one of the two geographical clusters which form the research area. Moreover, the number of respondents is not large, which increases the chance of flukes in the data. The low number of respondents is due to the fact the survey turned out to be too long and therefore had to be split into two separate surveys. Additionally, there are 10 non-traders present in the DCE, which may give a distorted image with regard to SPs. Probably, as a consequence, some results are in contrast to what can be expected based on the literature. A representative sample would almost certainly lead to different results. Last, stated preference may differ from revealed preference: respondents can make different choices than indicated if faced with a certain travel situation in reality.

This research has a quantitative approach by making use of a survey with a DCE. Therefore, this research has gained insight into the choices respondents make with regard to modal choice. A disadvantage however is that a quantitative approach does not gain insight into the reason why a certain mode is chosen over another. A complementary qualitative approach (mixed methods approach), asking why a respondent makes a certain choice, would give more in-depth insight into the context in which choices are made. Based on this, more specific results would be attained.

With regard to the survey, there are no answer categories which leave space for other interpretations ('other'). It may have led to forced responses (i.e. respondents have randomly chosen an answer category, because theirs was not available). An answer category 'other' should have been included for every question where other interpretations than the ones displayed are possible.

Last, there is no measuring instrument already available to study air-rail substitution. Hence, the operationalisation is largely based on the literature and on own interpretation when the literature fell short. Chances are therefore high the operationalisation is not perfect. For example, the group of spatial determinants is only operationalised by one and the same item. Moreover, the questions related to experience (the number of times travelled by air and rail in the five years before the COVID-19 pandemic) leave room for a rough estimation of the respondent, probably leading to unreliable answers. A different, more extensive

[8] The regression model has also been executed excluding 10 outliers, which did not lead to other outcomes. Moreover, there is no multicollinearity (see appendix E)

operationalisation would probably lead to different results, as the measuring instrument can be improved.

5.2 Recommendations

This research has answered a research question, but at the same time has initiated new research questions. Future research can always be done, evermore because the transport sector is changing rapidly due to on-going developments.

- First, if the European Commission want to actively promote rail transport and therefore stimulate air-rail substitution, they must study the effect of frequency and comfort of both air and rail on air-rail substitution more thoroughly in a separate study. With more time and means to collect data – including qualitative methods or a mixed methods approach which would reinforce results – this research can be carried out with a representative sample, most certainly leading to more reliable results on how both determinants influence air-rail substitution.
- Second, the DCE in this research includes some 'exaggerated' levels, which are experimental. The European air and notably rail sector is under constant development. In the (near) future, frequency, travel time, travel cost, comfort and the number of interchanges of both modes of transport may have changed drastically by for example the introduction of new HSR services, a rail market dominance of LCAs (see the former point) and a heavy flight tax. Therefore, future research with different levels in the DCE is needed in order to keep research on air-rail substitution up-to-date.
- Third, the recent rather successful application of the low-cost model to rail, and therefore the introduction of new LCT services, calls for a new perspective on the competitiveness of rail transport compared to air. Notably in France and Germany, new LCTs promise to be successful as they are more accessible to everyone in terms of travel cost than HSR services (Delaplace & Dobruszkes, 2015, p. 73). Moreover, the introduction of new night train routes may further change the European rail transport market (EC, 2021d, p. 7; Groen, 2022). The ability to save an overnight stay at the place of destination makes night trains cost- and time-attractive. However, as found in this research, travel time and cost are only moderately important determinants. Notwithstanding, both types of rail service will affect the existing transport market and most certainly the field of air-rail substitution too. Future research on the potential of these newly added rail services to compete with (low-cost) air services will shed a light on a new approach of air-rail substitution.
- Fourth, in order to seduce more people to choose the train, European operating rail companies, for example Thalys and Eurostar, not only have to improve travel cost and time into account, but must improve frequency and comfort of their services too. Moreover, they must also think of a way how to attract households with children and as experience matters as well, how to make travellers repetitiously choose for the train. If they want to attract more passengers, they must take into account both frequency and comfort as well when determining their future policy.
- Fifth and last, perhaps most importantly, a reasonable rail travel option as alternative of air travel must exist in the first place in order for air-ail substitution to take place. Therefore, national governments and the European Commission must keep on investing in the European (high-speed) rail network as they do now. Moreover, travel organisations usually only offer air travel: they should also offer rail travel if it is a reasonable alternative for a certain air journey.

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Appendix

A Research area

B Operationalisation

Construct	Indicator	Item
Socio-demographic determinants	Age	Age in numbers
	Income	Income class
	Household composition	Household class
	Car availability	Car available if needed
Socio-psychological determinants	Habit	Subscription to rail company Member of frequent flyer program Most frequently used mode for daily transport (all trips) Consideration alternative modes
	Awareness of climate change	Awareness climate change Worriedness climate change Action to mitigate climate change Encountering 'flight shame' Participation in carbon offset program
	Perception	Perceived expensiveness train journey Perceived duration train journey Perceived expensiveness plane journey Perceived duration plane journey
	Experience	Number of times travelled by train (cross-border, >400 kilometres) last 5 years (before COVID-19 pandemic) Number of times travelled by plane last 5 years (before COVID-19 pandemic)
Spatial determinants	Density and diversity	Postal code
	Proximity to infrastructure	Postal code

Journey determinants	Travel purpose	Leisure[9]
	Frequency	Amount of train services per hour
	Travel time	In-vehicle time Out-of-vehicle time (air)
	Travel cost	Flight tax (air)
	Comfort	Type of seat Availability of free Wi-Fi Free drink and snack or meal
	Interchange	Number of interchanges
	Importance journey determinants	Order of importance journey determinants
Air-rail substitution	Discrete choice model	27 choice sets

[9] Travel purpose in the SP design is set to leisure, because not everyone travels for business and leisure purposes determine most international trips for Dutch inhabitants (CBS, 2019). Moreover, varying travel purposes within the SP design would probably create confusion amongst respondents

C Discrete choice experiment

C.1 Alternatives, attributes and levels

Alternative	Attribute	Levels
Air	A_1: frequency	0 = 2-hourly 1 = 4-hourly 2 = 6-hourly
	A_2: travel time (in-vehicle)	0 = 1 hour 1 = 1.5 hours 2 = 2 hours
	A_3: travel time (out-of-vehicle)	0 = 2 hours 1 = 3 hours 2 = 4 hours
	A_4: travel cost	0 = €150 1 = €250 2 = €350
	A_5: comfort	0 = economy class seat, no Wi-Fi, no drink + snack 1 = economy comfort seat, no Wi-Fi, no drink + snack 2 = business class seat, free Wi-Fi, free drink + snack
Rail	R_1: frequency	0 = 1-hourly 1 = 2-hourly 2 = 3-hourly
	R_2: travel time	0 = 3 hours 1 = 4.5 hours 2 = 6 hours
	R_3: travel cost	0 = €100 1 = €200 2 = €300
	R_4: comfort	0 = 2nd class seat, free Wi-Fi, no meal 1 = 2nd class seat, free Wi-Fi, free meal 2 = 1st class seat, free Wi-Fi, free meal
	R_5: interchange	0 = no interchanges 1 = 1 interchange 2 = 2 interchanges

C.2 Choice sets

Choice set	Air					Rail				
	A_1	A_2	A_3	A_4	A_5	R_1	R_2	R_3	R_4	R_5
1	2-hourly	1.5 hours	2 hours	350 euros	economy comfort seat, no Wi-Fi, no drink + snack	2-hourly	3 hours	100 euros	2nd class seat, free Wi-Fi, free meal	2
2	6-hourly	1.5 hours	3 hours	350 euros	economy seat, no Wi-Fi, no drink + snack	1-hourly	4.5 hours	100 euros	2nd class seat, free Wi-Fi, no meal	0
3	4-hourly	2 hours	3 hours	350 euros	business class seat, free Wi-Fi, free drink + snack	1-hourly	3 hours	200 euros	2nd class seat, free Wi-Fi, free meal	1
4	4-hourly	1 hour	3 hours	250 euros	economy comfort seat, no Wi-Fi, no drink + snack	2-hourly	3 hours	200 euros	2nd class seat, free Wi-Fi, no meal	0

5	6-hourly	1 hour	2 hours	250 euros	business class seat, free Wi-Fi, free drink + snack	3-hourly	6 hours	200 euros	2nd class seat, free Wi-Fi, free meal	2
6	4-hourly	2 hours	4 hours	250 euros	economy comfort seat, no Wi-Fi, no drink + snack	1-hourly	6 hours	100 euros	2nd class seat, free Wi-Fi, free meal	0
7	2-hourly	1 hour	4 hours	250 euros	economy seat, no Wi-Fi, no drink + snack	1-hourly	4.5 hours	200 euros	1st class seat, free Wi-Fi, free meal	1
8	4-hourly	1.5 hours	2 hours	250 euros	economy comfort seat, no Wi-Fi, no drink + snack	3-hourly	4.5 hours	300 euros	1st class seat, free Wi-Fi, free meal	0
9	6-hourly	2 hours	3 hours	250 euros	business class seat, free Wi-Fi, free drink + snack	2-hourly	4.5 hours	100 euros	1st class seat, free Wi-Fi, free meal	2
10	6-hourly	1 hour	4 hours	350 euros	economy seat, no Wi-Fi, no drink + snack	3-hourly	3 hours	300 euros	2nd class seat, free Wi-Fi, free meal	0
11	4-hourly	2 hours	2 hours	150 euros	economy seat, no Wi-Fi, no drink + snack	1-hourly	4.5 hours	300 euros	2nd class seat, free Wi-Fi, free meal	2
12	2-hourly	2 hours	3 hours	150 euros	business class seat, free Wi-Fi, free drink + snack	3-hourly	6 hours	300 euros	2nd class seat, free Wi-Fi, no meal	0
13	2-hourly	1.5 hours	4 hours	150 euros	business class seat, free Wi-Fi, free drink + snack	2-hourly	4.5 hours	200 euros	2nd class seat, free Wi-Fi, free meal	0
14	6-hourly	2 hours	4 hours	150 euros	economy comfort seat, no Wi-Fi, no drink	2-hourly	3 hours	300 euros	1st class seat, free Wi-Fi, free meal	1
15	2-hourly	2 hours	2 hours	250 euros	economy seat, no Wi-Fi, no drink + snack	3-hourly	3 hours	100 euros	2nd class seat, free Wi-Fi, no meal	1
16	4-hourly	1 hour	2 hours	350 euros	business class seat, free Wi-Fi, free drink + snack	2-hourly	4.5 hours	300 euros	2nd class seat, free Wi-Fi, no meal	1
17	2-hourly	1 hour	3 hours	350 euros	economy comfort seat, no Wi-Fi, no drink + snack	1-hourly	6 hours	300 euros	1st class seat, free Wi-Fi, free meal	2
18	2-hourly	1 hour	2 hours	150 euros	business class seat, free Wi-Fi, free drink + snack	1-hourly	3 hours	100 euros	1st class seat, free Wi-Fi, free meal	0
19	6-hourly	1.5 hours	2 hours	150 euros	economy comfort seat, no Wi-Fi, no drink + snack	1-hourly	6 hours	200 euros	2nd class seat, free Wi-Fi, no meal	1
20	2-hourly	2 hours	4 hours	350 euros	economy comfort seat, no Wi-Fi, no drink + snack	3-hourly	4.5 hours	200 euros	2nd class seat, free Wi-Fi, no meal	2
21	6-hourly	1 hour	3 hours	150 euros	economy comfort seat, no Wi-Fi, no drink + snack	3-hourly	4.5 hours	100 euros	2nd class seat, free Wi-Fi, free meal	1
22	4-hourly	1 hour	4 hours	150 euros	economy seat, no Wi-Fi, no drink + snack	2-hourly	6 hours	100 euros	2nd class seat, free Wi-Fi, no meal	2
23	2-hourly	1.5 hours	3 hours	250 euros	economy seat, no Wi-Fi, no drink + snack	2-hourly	6 hours	300 euros	2nd class seat, free Wi-Fi, free meal	1
24	6-hourly	1.5 hours	4 hours	250 euros	business class seat, free Wi-Fi, free drink + snack	1-hourly	3 hours	300 euros	2nd class seat, free Wi-Fi, no meal	2
25	4-hourly	1.5 hours	4 hours	350 euros	business class seat, free Wi-Fi, free drink + snack	3-hourly	6 hours	100 euros	1st class seat, free Wi-Fi, free meal	1
26	6-hourly	2 hours	2 hours	350 euros	economy seat, no Wi-Fi, no drink + snack	2-hourly	6 hours	200 euros	1st class seat, free Wi-Fi, free meal	0
27	4-hourly	1.5 hours	3 hours	150 euros	economy seat, no Wi-Fi, no drink + snack	3-hourly	3 hours	200 euros	1st class seat, free Wi-Fi, free meal	2

D Statistical tests

Construct	Statistical test
Likert scale	Item-analysis
Discrete choice model	Binary logistic regression Hosmer-Lemeshow Test

E SPSS output

E.1 Item-analysis

Case Processing Summary

		N	%
Cases	Valid	79	100.0
	Excluded[a]	0	.0
	Total	79	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.762	5

Item Statistics

	Mean	Std. Deviation	N
I am aware of climate change	4.35	.661	79
I am worried about climate change	3.89	1.109	79
I take action to mitigate climate change	3.63	1.179	79
I have 'flight shame' (feeling uneasy to fly because of environmental damage done when flying)	2.27	1.216	79
I would pay for my carbon offset (CO2) when flying if the possibility exists	2.89	1.349	79

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
I am aware of climate change	12.67	14.044	.363	.771
I am worried about climate change	13.14	9.660	.782	.626
I take action to mitigate climate change	13.39	11.036	.492	.733
I have 'flight shame' (feeling uneasy to fly	14.76	10.364	.567	.706

because of environmental damage done when flying)				
I would pay for my carbon offset (CO_2) when flying if the possibility exists	14.14	10.096	.509	.734

Case Processing Summary

		N	%
Cases	Valid	79	100.0
	Excluded[a]	0	.0
	Total	79	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.242	4

Item Statistics

	Mean	Std. Deviation	N
I believe traveling by train is cheap	2.19	1.075	79
I believe traveling by train is fast	2.82	1.047	79
I believe traveling by plane is cheap	2.75	1.103	79
I believe traveling by plane is fast	2.10	.886	79

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
I believe traveling by train is cheap	7.67	2.942	.299	-.080[a]
I believe traveling by train is fast	7.04	3.704	.099	.221
I believe traveling by plane is cheap	7.11	4.154	-.038	.403
I believe traveling by plane is fast	7.76	3.852	.162	.149

a. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item codings.

E.2 Binary logistic regression

Presupposition	Presupposition met?
The dependent variables are dichotomous. The independent variables are interval/ratio, or categorical	Yes
The link is theoretically causal. The logit is influenced by every independent variable	Yes
The model is linear. The logit is a linear combination of the independent variables	This presupposition is hard to verify
There is no multicollinearity[10] between the interval/ratio variables. There are no bivariate correlations of $\lvert r \rvert \geq 0.9$	Yes (see below)

Correlations

Pearson Correlation

	Age	I am aware of climate change	I am worried about climate change	I take action to mitigate climate change (for example, walking instead of driving for short trips)	I have 'flight shame' (feeling uneasy to fly because of environmental damage done when flying)	I would pay for my carbon offset (CO2) when flying if the possibility exists	I believe traveling by train is cheap	I believe traveling by train is fast	I believe traveling by plane is cheap	I believe traveling by plane is fast	How many times did you approximately travel by plane?	How many times did you approximately travel by train?
Age	1	-.195**	-.158**	.069*	-.138**	-0.055	.078*	.069*	-0.028	0.035	0.043	.425**
I am aware of climate change	-.195**	1	.428**	.223**	.265**	.240**	-.221**	-.149**	.104**	-.243**	.107**	-.312**
I am worried about climate change	-.158**	.428**	1	.553**	.573**	.592**	.092**	.246**	.062*	-.137**	0.012	-.204**
I take action to mitigate climate change (for example, walking instead of driving for short trips)	.069*	.223**	.553**	1	.407**	.282**	.135**	.327**	.075*	-.157**	-0.014	.113**
I have 'flight shame' (feeling uneasy to fly because of environmental damage done when flying)	-.138**	.265**	.573**	.407**	1	.398**	0.047	.137**	.266**	-.102**	-.110**	-0.054

10 Multicollinearity is also checked by the variance inflation factor (VIF). The VIF for all variables is under 5, except for age (6.399)

I would pay for my carbon offset (CO2) when flying if the possibility exists	-0.055	.240**	.592**	.282**	.398**	1	.086**	-0.009	-.078*	-0.004	0.001	-.252**
I believe traveling by train is cheap	.078*	-.221**	.092**	.135**	0.047	.086**	1	.189**	-.159**	-.155**	-0.023	.211**
I believe traveling by train is fast	.069*	-.149**	.246**	.327**	.137**	-0.009	.189**	1	.181**	-.210**	-0.030	.118**
I believe traveling by plane is cheap	-0.028	.104**	.062*	.075*	.266**	-.078*	-.159**	.181**	1	-.063*	0,029	.121**
I believe traveling by plane is fast	0.035	-.243**	-.137**	-.157**	-.102**	-0.004	-.155**	-.210**	-.063*	1	-0.027	.079*
How many times did you approximately travel by plane?	0.043	.107**	0.012	-0.014	-.110**	0.001	-0.023	-0.030	0.029	-0.027	1	-.099**
How many times did you approximately travel by train?	.425**	-.312**	-.204**	.113**	-0.054	-.252**	.211**	.118**	.121**	.079*	-.099**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	1044	98.7
	Missing Cases	14	1.3
	Total	1058	100.0
Unselected Cases		0	.0
Total		1058	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Original Value	Internal Value
Air	0
Train	1

Categorical Variables Codings

		Frequency	Parameter coding (1)	(2)	(3)	(4)	(5)	(6)
Household composition	Together with friend(s)/student(s)	185	.000	.000	.000	.000	.000	.000
	Together with parent(s), with or without siblings	386	1.000	.000	.000	.000	.000	.000
	Single without children	106	.000	1.000	.000	.000	.000	.000
	Couple without children	120	.000	.000	1.000	.000	.000	.000
	Couple with 1 child	95	.000	.000	.000	1.000	.000	.000
	Couple with 2 children	96	.000	.000	.000	.000	1.000	.000
	Couple with 3 or more children	56	.000	.000	.000	.000	.000	1.000
Employment status	School-going or student	583	.000	.000	.000	.000		
	Employed (full-time)	244	1.000	.000	.000	.000		
	Employed (part-time)	110	.000	1.000	.000	.000		
	Self-employed	41	.000	.000	1.000	.000		
	Retired or unable to work	66	.000	.000	.000	1.000		
Which mode of transport do you use most on a daily basis?	Car	490	.000	.000	.000	.000		
	Scooter, moped or motorcycle	40	1.000	.000	.000	.000		
	Train	117	.000	1.000	.000	.000		
	Bus, tram or metro	14	.000	.000	1.000	.000		
	Active mode (for example, walking or cycling)	383	.000	.000	.000	1.000		
Highest level of education	Level 1: primary education	39	.000	.000	.000	.000		
	Level 2: vmbo, mbo1	27	1.000	.000	.000	.000		
	Level 3: havo, vwo, mbo	248	.000	1.000	.000	.000		
	Level 4: hbo, wo bachelor	677	.000	.000	1.000	.000		
	Level 5: wo master, doctor	53	.000	.000	.000	1.000		
Income class	€2000 or less	666	.000	.000	.000			

	€2000-€4000	162	1.000	.000	.000			
	€4000 or more	109	.000	1.000	.000			
	Prefer not to say	107	.000	.000	1.000			
Do you have a subscription to a rail company?	Yes, a subscription for free travel (for example, free travel during weekends)	505	.000	.000				
	Yes, a subscription for discount (for example, 40% off during non-peak hours)	147	1.000	.000				
	No	392	.000	1.000				
Frequency (air)	2[11]	343	.000	.000				
	4	357	1.000	.000				
	6	344	.000	1.000				
Interchanges (rail)	0	386	.000	.000				
	1	315	1.000	.000				
	2	343	.000	1.000				
Out-of-vehicle time (air)	2	376	.000	.000				
	3	357	1.000	.000				
	4	311	.000	1.000				
Travel cost (air)	150	330	.000	.000				
	250	372	1.000	.000				
	350	342	.000	1.000				
Comfort (air)	0	344	.000	.000				
	1	343	1.000	.000				
	2	357	.000	1.000				
Frequency (rail)	1	357	.000	.000				
	2	344	1.000	.000				
	3	343	.000	1.000				
Travel time (rail)	3.0	344	.000	.000				
	4.5	372	1.000	.000				
	6.0	328	.000	1.000				

[11] Labels are corresponding to the values they propagate and therefore not labelled from 0 to 2

Travel cost (rail)	100	343	.000	.000					
	200	358	1.000	.000					
	300	343	.000	1.000					
Comfort (rail)	0	330	.000	.000					
	1	386	1.000	.000					
	2	328	.000	1.000					
In-vehicle time (air)	1.0	343	.000	.000					
	1.5	343	1.000	.000					
	2.0	358	.000	1.000					
Car availability	No	211	.000						
	Yes	833	1.000						
Place of residence	rural	608	.000						
	urban	436	1.000						
Did you consider traveling by other modes of transport as well for this journey?	Yes	319	.000						
	No	725	1.000						
Are you member of a frequent flyer program?	Yes	229	.000						
	No	815	1.000						
Gender	Male	537	.000						
	Female	507	1.000						

Classification Table[a,b]

			Predicted		
			Air or rail		Percentage Correct
	Observed		Air	Train	
Step 0	Air or rail	Air	0	457	.0
		Train	0	587	100.0
	Overall Percentage				56.2

a. Constant is included in the model.

b. The cut value is .500

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	619.568	60	<.001
	Block	619.568	60	<.001

	Model	619.568	60	<.001

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	811.494[a]	.448	.600

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	13.115	8	.108

Contingency Table for Hosmer and Lemeshow Test

		Air or rail = Air		Air or rail = Train		
		Observed	Expected	Observed	Expected	Total
Step 1	1	97	101.223	7	2.777	104
	2	94	93.829	10	10.171	104
	3	80	81.135	24	22.865	104
	4	75	66.160	29	37.840	104
	5	46	48.363	58	55.637	104
	6	37	32.299	67	71.701	104
	7	17	19.150	87	84.850	104
	8	7	9.901	97	94.099	104
	9	4	4.202	100	99.798	104
	10	0	.739	108	107.261	108

Classification Table[a]

			Predicted		
			Air or rail		Percentage Correct
Observed			Air	Train	
Step 1	Air or rail	Air	363	94	79.4
		Train	84	503	85.7
	Overall Percentage				83.0

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Age	-.052	.019	7.580	1	.006	.949
	Gender(1)	-.546	.304	3.225	1	.073	.579
	Household composition			41.460	6	<.001	
	Household composition(1)	-1.581	.473	11.166	1	<.001	.206

	Household composition(2)	-2.713	.539	25.294	1	<.001	.066
	Household composition(3)	-1.226	.524	5.476	1	.019	.293
	Household composition(4)	-2.885	.753	14.660	1	<.001	.056
	Household composition(5)	-.016	.739	.000	1	.983	.984
	Household composition(6)	-2.238	.808	7.671	1	.006	.107
	Highest level of education			12.582	4	.014	
	Highest level of education(1)	-3.655	1.575	5.384	1	.020	.026
	Highest level of education(2)	-1.923	.881	4.770	1	.029	.146
	Highest level of education(3)	-2.491	.883	7.957	1	.005	.083
	Highest level of education(4)	-1.867	1.098	2.894	1	.089	.155
	Employment status			13.866	4	.008	
	Employment status(1)	.496	.566	.767	1	.381	1.642
	Employment status(2)	.758	.469	2.613	1	.106	2.135
	Employment status(3)	-1.624	1.032	2.477	1	.116	.197
	Employment status(4)	2.686	.945	8.080	1	.004	14.666
	Income class			3.017	3	.389	
	Income class(1)	1.110	.660	2.826	1	.093	3.035
	Income class(2)	.928	.773	1.441	1	.230	2.529
	Income class(3)	.410	.517	.627	1	.428	1.506
	Car availability(1)	.498	.390	1.630	1	.202	1.646
	Do you have a subscription to a rail company?			14.603	2	<.001	
	Do you have a subscription to a rail company?(1)	-1.671	.462	13.079	1	<.001	.188
	Do you have a subscription to a rail company?(2)	-.823	.361	5.191	1	.023	.439
	Are you member of a frequent flyer program?(1)	-.095	.379	.063	1	.803	.910
	Which mode of transport do you use most on a daily basis?			23.236	4	<.001	
	Which mode of transport do you use most on a daily basis?(1)	1.773	.630	7.925	1	.005	5.891

	Which mode of transport do you use most on a daily basis?(2)	1.683	.457	13.578	1	<.001	5.379
	Which mode of transport do you use most on a daily basis?(3)	-1.226	.903	1.842	1	.175	.293
	Which mode of transport do you use most on a daily basis?(4)	1.216	.411	8.760	1	.003	3.375
	Did you consider traveling by other modes of transport as well for this journey?(1)	-.725	.255	8.077	1	.004	.485
	I am aware of climate change	.372	.274	1.835	1	.176	1.450
	I am worried about climate change	.319	.194	2.709	1	.100	1.376
	I take action to mitigate climate change (for example, walking instead of driving for short trips)	.037	.138	.072	1	.788	1.038
	I have 'flight shame' (feeling uneasy to fly because of environmental damage done when flying)	.626	.176	12.620	1	<.001	1.870
	I would pay for my carbon offset (CO2) when flying if the possibility exists	-.185	.113	2.703	1	.100	.831
	I believe traveling by train is cheap	-.441	.132	11.185	1	<.001	.643
	I believe traveling by train is fast	.250	.148	2.839	1	.092	1.284
	I believe traveling by plane is cheap	.097	.123	.618	1	.432	1.102
	I believe traveling by plane is fast	-.287	.146	3.873	1	.049	.750
	How many times did you approximately travel by plane?	-.045	.025	3.212	1	.073	.956
	How many times did you approximately travel by train?	.264	.043	37.439	1	<.001	1.302
	Place of residence(1)	-1.001	.318	9.904	1	.002	.368
	Frequency (air)			78.903	2	<.001	
	Frequency (air)(1)	-.538	.223	5.830	1	.016	.584
	Frequency (air)(2)	-2.035	.236	74.378	1	<.001	.131
	In-vehicle time (air)			9.806	2	.007	

	In-vehicle time (air)(1)	-.068	.227	.090	1	.764	.934
	In-vehicle time (air)(2)	.556	.218	6.513	1	.011	1.744
	Out-of-vehicle time (air)			1.545	2	.462	
	Out-of-vehicle time (air)(1)	-.272	.219	1.536	1	.215	.762
	Out-of-vehicle time (air)(2)	-.123	.242	.260	1	.610	.884
	Travel cost (air)			13.745	2	.001	
	Travel cost (air)(1)	-.728	.241	9.138	1	.003	.483
	Travel cost (air)(2)	-.739	.220	11.344	1	<.001	.477
	Comfort (air)			78.611	2	<.001	
	Comfort (air)(1)	.550	.219	6.318	1	.012	1.733
	Comfort (air)(2)	-1.560	.232	45.354	1	<.001	.210
	Frequency (rail)			44.422	2	<.001	
	Frequency (rail)(1)	1.160	.228	25.841	1	<.001	3.191
	Frequency (rail)(2)	-.320	.221	2.093	1	.148	.726
	Travel time (rail)			11.155	2	.004	
	Travel time (rail)(1)	-.689	.224	9.469	1	.002	.502
	Travel time (rail)(2)	-.078	.231	.114	1	.736	.925
	Travel cost (rail)			13.487	2	.001	
	Travel cost (rail)(1)	-.013	.225	.003	1	.954	.987
	Travel cost (rail)(2)	.699	.227	9.447	1	.002	2.012
	Comfort (rail)			48.400	2	<.001	
	Comfort (rail)(1)	-1.098	.245	20.057	1	<.001	.334
	Comfort (rail)(2)	-1.578	.230	47.173	1	<.001	.206
	Interchanges (rail)			8.386	2	.015	
	Interchanges (rail)(1)	.542	.249	4.742	1	.029	1.720
	Interchanges (rail)(2)	-.094	.234	.162	1	.687	.910
	Constant	5.009	1.910	6.879	1	.009	149.702

a. Variable(s) entered on step 1: Age, Gender, Household composition, Highest level of education, Employment status, Income class, Car availability, Do you have a subscription to a rail company?, Are you member of a frequent flyer program?, Which mode of transport do you use most on a daily basis?, Did you consider traveling by other modes of transport as well for this journey?, I am aware of climate change, I am worried about climate change, I take action to mitigate climate change (for example, walking instead of driving for short trips), I have 'flight shame' (feeling uneasy to fly because of environmental damage done when flying), I would pay for my carbon offset (CO2) when flying if the possibility exists, I believe traveling by train is cheap, I believe traveling by train is fast, I believe traveling by plane is cheap, I believe traveling by plane is fast, How many times did you approximately travel by plane?, How many times did you approximately travel by train?, Place of residence, Frequency (air), In-vehicle time (air), Out-of-vehicle time (air), Travel cost (air), Comfort (air), Frequency (rail), Travel time (rail), Travel cost (rail), Comfort (rail), Interchanges (rail).

F Survey

First of all, thank you for your willingness and time to take this survey! My name is Jochem Bezemer and for my master's thesis at Utrecht University, I am conducting research on modal choice (the decision for a mode of transport for a journey) of long-distance trips within Europe, most notably both the plane and the train. By taking the survey, you help finishing my research project successfully. It takes around 10 minutes and is fully anonymous. For questions and/or remarks, feel free to contact me via e-mail: j.bezemer2@students.uu.nl.

Q1 What is your age?

____

Q2 What is your gender?

○ Male (1)

○ Female (2)

○ Non-binary (3)

○ Prefer not to say (4)

Q3 What is your household composition?

○ Together with friend(s)/student(s) (1)

○ Together with parent(s), with or without siblings (2)

○ Single without children (3)

○ Single with child(ren) (4)

○ Couple without children (5)

○ Couple with 1 child (6)

○ Couple with 2 children (7)

○ Couple with 3 or more children (8)

Q4 What is your highest achieved level of education?

- ◯ Level 1: primary education (1)
- ◯ Level 2: vmbo, mbo1 (2)
- ◯ Level 3: havo, vwo, mbo (3)
- ◯ Level 4: hbo, wo bachelor (4)
- ◯ Level 5: wo master, doctor (5)

Q5 What is your current employment status?

- ◯ School-going or student (1)
- ◯ Volunteer (2)
- ◯ Employed (full-time) (3)
- ◯ Employed (part-time) (4)
- ◯ Self-employed (5)
- ◯ Unemployed (6)
- ◯ Retired or unable to work (7)

Q6 Which income class describes your individual situation best?

- ◯ €2000 or less (1)
- ◯ €2000-€4000 (2)
- ◯ €4000 or more (3)
- ◯ Prefer not to say (4)

Q7 What are the four numbers of your postal code? **Your postal code will only be used to compare results**

____

Q8 Do you have a car to your availability, in case you need one (you do not have to own the car)?

- ◯ Yes (1)
- ◯ No (2)

Q9 How many times did you approximately travel by plane the last 5 years before the COVID-19 pandemic (2015-2020)?

____

Q10 How many times did you approximately travel by train (international and more than 400 kilometers) the last 5 years before the COVID-19 pandemic (2015-2020)?

____

Q11 Do you have a subscription to a rail company (for example, NS)?

- ○ Yes, a subscription for free travel (for example, free travel during weekends) (1)
- ○ Yes, a subscription for discount (for example, 40% off during non-peak hours) (2)
- ○ No (3)

Q12 Are you member of a frequent flyer program (for example, Flying Blue)?

- ○ Yes (1)
- ○ No (2)

Q13 Which mode of transport do you use most on a daily basis?

- ○ Car (1)
- ○ Scooter, moped or motorcycle (2)
- ○ Train (3)
- ○ Bus, tram or metro (4)
- ○ Active mode (for example, walking or cycling) (5)

Q14 Think of your last international journey more than 400 kilometers in length (made by car, train or plane). Did you consider traveling by other modes of transport as well for this journey?

- ○ Yes (1)
- ○ No (2)

In this part of the survey, you will state your preference for either air or rail travel in different situations. These situations can sometimes be different from reality, because the international travel market is changing. It is important to keep your personal environment in mind at all times:

for example, if you are a couple with 2 children, you are traveling with your whole household. **Your travel purpose is always leisure (for example, a holiday)**.

Before you start, some clarification is needed:

- **Frequency** is the number of planes or trains per time interval and therefore the waiting time in case of cancellation or missing your flight or train.

- Rail travel brings you directly to the city centre/destination, while air travel brings you to an airport outside the city. Therefore, air travel time is split into **in-vehicle time** (duration of the flight) and **out-of-vehicle time** (waiting time at the airport + travel time from home to the airport and from the airport to the final destination).

- Rail travel includes the number of **interchanges**, because this is common in international rail travel.

Choose which mode of transport, air or rail, you would prefer given a certain situation.

Q15 Choose which mode of transport, air or rail, you would prefer for this situation
* Economy comfort class is a seat with more legroom

	Frequency **2-hourly** Travel time (in-vehicle) **1.5 hours** Travel time (out-of-vehicle) **2 hours** Travel cost **€350** Comfort **Economy comfort class***	Frequency **2-hourly** Travel time **3 hours** Travel cost **€100** Comfort **Second class, Wi-Fi, free meal** Interchanges **2**
What mode would you prefer? (1)	Air (1) ☐	Rail (1) ☐

Q16 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **6-hourly** Travel time (in-vehicle) **1.5 hours** Travel time (out-of-vehicle) **3 hours** Travel cost **€350** Comfort **Economy class**	Frequency **1-hourly** Travel time **4.5 hours** Travel cost **€100** Comfort **Second class, Wi-Fi** Interchanges **0**

	Air (1)	Rail (1)
What mode would you prefer? (1)	▢	▢

Q17 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **4-hourly** Travel time (in-vehicle) **2 hours** Travel time (out-of-vehicle) **3 hours** Travel cost **€350** Comfort **Business class, Wi-Fi, drink + snack**	Frequency **1-hourly** Travel time **3 hours** Travel cost **€200** Comfort **Second class, Wi-Fi, free meal** Interchanges **1**
	Air (1)	Rail (1)
What mode would you prefer? (1)	▢	▢

Q18 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **4-hourly** Travel time (in-vehicle) **1 hour** Travel time (out-of-vehicle) **3 hours** Travel cost **€250** Comfort **Economy comfort class**	Frequency **2-hourly** Travel time **3 hours** Travel cost **€200** Comfort **Second class, Wi-Fi** Interchanges **0**
	Air (1)	Rail (1)
What mode would you prefer? (1)	▢	▢

Q19 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **6-hourly** Travel time (in-vehicle) **1 hour** Travel time (out-of-vehicle) **2 hours** Travel cost **€250** Comfort **Business class, Wi-Fi, drink + snack**	Frequency **3-hourly** Travel time **6 hours** Travel cost **€200** Comfort **Second class, Wi-Fi, free meal** Interchanges **2**

	Air (1)	Rail (1)
What mode would you prefer? (1)	▢	▢

Q20 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **4-hourly** Travel time (in-vehicle) **2 hours** Travel time (out-of-vehicle) **4 hours** Travel cost **€250** Comfort **Economy comfort class**	Frequency **1-hourly** Travel time **6 hours** Travel cost **€100** Comfort **Second class, Wi-Fi, free meal** Interchanges **0**
	Air (1)	Rail (1)
What mode would you prefer? (1)	▢	▢

Q21 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **2-hourly** Travel time (in-vehicle) **1 hour** Travel time (out-of-vehicle) **4 hours** Travel cost **€250** Comfort **Economy class**	Frequency **1-hourly** Travel time **4.5 hours** Travel cost **€200** Comfort **First class, Wi-Fi, free meal** Interchanges **1**
	Air (1)	Rail (1)
What mode would you prefer? (1)	▢	▢

Q22 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **4-hourly** Travel time (in-vehicle) **1.5 hours** Travel time (out-of-vehicle) **2 hours** Travel cost **€250** Comfort **Economy comfort class**	Frequency **3-hourly** Travel time **4.5 hours** Travel cost **€300** Comfort **First class, Wi-Fi, free meal** Interchanges **0**

	Air (1)	Rail (1)
What mode would you prefer? (1)	☐	☐

Q23 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **6-hourly** Travel time (in-vehicle) **2 hours** Travel time (out-of-vehicle) **3 hours** Travel cost **€250** Comfort **Business class, Wi-Fi, drink + snack**	Frequency **2-hourly** Travel time **4.5 hours** Travel cost **€100** Comfort **First class, Wi-Fi, free meal** Interchanges **2**
	Air (1)	Rail (1)
What mode would you prefer? (1)	☐	☐

Q24 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **6-hourly** Travel time (in-vehicle) **1 hour** Travel time (out-of-vehicle) **4 hours** Travel cost **€350** Comfort **Economy class**	Frequency **3-hourly** Travel time **3 hours** Travel cost **€300** Comfort **Second class, Wi-Fi, free meal** Interchanges **0**
	Air (1)	Rail (1)
What mode would you prefer? (1)	☐	☐

Q25 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **4-hourly** Travel time (in-vehicle) **2 hours** Travel time (out-of-vehicle) **2 hours** Travel cost **€150** Comfort **Economy class**	Frequency **1-hourly** Travel time **4.5 hours** Travel cost **€300** Comfort **Second class, Wi-Fi, free meal** Interchanges

		2
	Air (1)	Rail (1)
What mode would you prefer? (1)	☐	☐

Q26 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **2-hourly** Travel time (in-vehicle) **2 hours** Travel time (out-of-vehicle) **3 hours** Travel cost **€150** Comfort **Business class, Wi-Fi, drink + snack**	Frequency **3-hourly** Travel time **6 hours** Travel cost **€300** Comfort **Second class, Wi-Fi** Interchanges **0**
	Air (1)	Rail (1)
What mode would you prefer? (1)	☐	☐

Q27 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **2-hourly** Travel time (in-vehicle) **1.5 hours** Travel time (out-of-vehicle) **4 hours** Travel cost **€150** Comfort **Business class, Wi-Fi, drink + snack**	Frequency **2-hourly** Travel time **4.5 hours** Travel cost **€200** Comfort **Second class, Wi-Fi, free meal** Interchanges **0**
	Air (1)	Rail (1)
What mode would you prefer? (1)	☐	☐

Q28 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **6-hourly** Travel time (in-vehicle) **2 hours** Travel time (out-of-vehicle) **4 hours** Travel cost **€150**	Frequency **2-hourly** Travel time **3 hours** Travel cost **€300** Comfort

	Comfort **Economy comfort class**	**First class, Wi-Fi, free meal** Interchanges **1**
What mode would you prefer? (1)	Air (1) ☐	Rail (1) ☐

Q29 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **2-hourly** Travel time (in-vehicle) **2 hours** Travel time (out-of-vehicle) **2 hours** Travel cost **€250** Comfort **Economy class**	Frequency **3-hourly** Travel time **3 hours** Travel cost **€100** Comfort **Second class, Wi-Fi** Interchanges **1**
What mode would you prefer? (1)	Air (1) ☐	Rail (1) ☐

Q30 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **4-hourly** Travel time (in-vehicle) **1 hour** Travel time (out-of-vehicle) **2 hours** Travel cost **€350** Comfort **Business class, Wi-Fi, drink + snack**	Frequency **2-hourly** Travel time **4.5 hours** Travel cost **€300** Comfort **Second class, Wi-Fi** Interchanges **1**
What mode would you prefer? (1)	Air (1) ☐	Rail (1) ☐

Q31 Choose which mode of transport, air or rail, you would prefer for this situation

* Economy comfort class is a seat with more legroom

	Frequency **2-hourly** Travel time (in-vehicle) **1 hour** Travel time (out-of-vehicle)	Frequency **1-hourly** Travel time **6 hours** Travel cost

	3 hours Travel cost **€350** Comfort **Economy comfort class***	**€300** Comfort **First class, Wi-Fi, free meal** Interchanges **2**
What mode would you prefer? (1)	Air (1) ☐	Rail (1) ☐

Q32 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **2-hourly** Travel time (in-vehicle) **1 hour** Travel time (out-of-vehicle) **2 hours** Travel cost **€150** Comfort **Business class, Wi-Fi, drink + snack**	Frequency **1-hourly** Travel time **3 hours** Travel cost **€100** Comfort **First class, Wi-Fi, free meal** Interchanges **0**
What mode would you prefer? (1)	Air (1) ☐	Rail (1) ☐

Q33 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **6-hourly** Travel time (in-vehicle) **1.5 hours** Travel time (out-of-vehicle) **2 hours** Travel cost **€150** Comfort **Economy comfort class**	Frequency **1-hourly** Travel time **6 hours** Travel cost **€200** Comfort **Second class, Wi-Fi** Interchanges **1**
What mode would you prefer? (1)	Air (1) ☐	Rail (1) ☐

Q34 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **2-hourly** Travel time (in-vehicle) **2 hours** Travel time (out-of-vehicle)	Frequency **3-hourly** Travel time **4.5 hours** Travel cost

	4 hours Travel cost **€350** Comfort **Economy comfort class**	**€200** Comfort **Second class, Wi-Fi** Interchanges **2**
	Air (1)	Rail (1)
What mode would you prefer? (1)	☐	☐

Q35 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **6-hourly** Travel time (in-vehicle) **1 hour** Travel time (out-of-vehicle) **3 hours** Travel cost **€150** Comfort **Economy comfort class**	Frequency **3-hourly** Travel time **4.5 hours** Travel cost **€100** Comfort **Second class, Wi-Fi, free meal** Interchanges **1**
	Air (1)	Rail (1)
What mode would you prefer? (1)	☐	☐

Q36 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **4-hourly** Travel time (in-vehicle) **1 hour** Travel time (out-of-vehicle) **4 hours** Travel cost **€150** Comfort **Economy class**	Frequency **2-hourly** Travel time **6 hours** Travel cost **€100** Comfort **Second class, Wi-Fi** Interchanges **2**
	Air (1)	Rail (1)
What mode would you prefer? (1)	☐	☐

Q37 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **2-hourly** Travel time (in-vehicle) **1.5 hours** Travel time (out-of-vehicle)	Frequency **2-hourly** Travel time **6 hours** Travel cost

	3 hours Travel cost **€250** Comfort **Economy class**	**€300** Comfort **Second class, Wi-Fi, free meal** Interchanges **1**
	Air (1)	Rail (1)
What mode would you prefer? (1)	▢	▢

Q38 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **6-hourly** Travel time (in-vehicle) **1.5 hours** Travel time (out-of-vehicle) **4 hours** Travel cost **€250** Comfort **Business class, Wi-Fi, drink + snack**	Frequency **1-hourly** Travel time **3 hours** Travel cost **€300** Comfort **Second class, Wi-Fi** Interchanges **2**
	Air (1)	Rail (1)
What mode would you prefer? (1)	▢	▢

Q39 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **4-hourly** Travel time (in-vehicle) **1.5 hours** Travel time (out-of-vehicle) **4 hours** Travel cost **€350** Comfort **Business class, Wi-Fi, drink + snack**	Frequency **3-hourly** Travel time **6 hours** Travel cost **€100** Comfort **First class, Wi-Fi, free meal** Interchanges **1**
	Air (1)	Rail (1)
What mode would you prefer? (1)	▢	▢

Q40 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **6-hourly** Travel time (in-vehicle)	Frequency **2-hourly** Travel time

	2 hours Travel time (out-of-vehicle) **2 hours** Travel cost **€350** Comfort **Economy class**	**6 hours** Travel cost **€200** Comfort **First class, Wi-Fi, free meal** Interchanges **0**
	Air (1)	Rail (1)
What mode would you prefer? (1)	▢	▢

Q41 Choose which mode of transport, air or rail, you would prefer for this situation

	Frequency **4-hourly** Travel time (in-vehicle) **1.5 hours** Travel time (out-of-vehicle) **3 hours** Travel cost **€150** Comfort **Economy class**	Frequency **3-hourly** Travel time **3 hours** Travel cost **€200** Comfort **First class, Wi-Fi, free meal** Interchanges **2**
	Air (1)	Rail (1)
What mode would you prefer? (1)	▢	▢

Q42 Rank in order which journey characteristics are important to you when you choose a mode of transport, from most important (1) to least important (6)

_______ Interchanges (1)
_______ In-vehicle travel time (2)
_______ Frequency (3)
_______ Comfort (4)
_______ Travel cost (5)
_______ Out-of-vehicle travel time (6)

Q43 The final part of this survey consists of some statements.

To what extent do you agree or disagree with the following statements?

	Strongly disagree (1)	Somewhat disagree (2)	Neither disagree or agree (3)	Somewhat agree (4)	Strongly agree (5)
I am aware of climate change (1)	○	○	○	○	○
I am worried about climate change (2)	○	○	○	○	○
I take action to mitigate climate change (for example, walking instead of driving for short trips) (3)	○	○	○	○	○
I have 'flight shame' (feeling uneasy to fly because of environmental damage done when flying) (4)	○	○	○	○	○
I would pay for my carbon offset (CO2) when flying if the possibility exists (5)	○	○	○	○	○
I believe traveling by train is cheap (6)	○	○	○	○	○
I believe traveling by train is fast (7)	○	○	○	○	○
I believe traveling by plane is cheap (8)	○	○	○	○	○
I believe traveling by plane is fast (9)	○	○	○	○	○