High speed rail versus air travel on short-haul destinations

A case study for Amsterdam-London and Amsterdam Berlin: influencing modality choice with help of the behavioural change matrix

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Abstract

This research focuses on the modality choice of people and which factors contribute to this choice. High speed rail is becoming more and more a competitor for the traditional air travel on certain corridors. An important part of this research is the environmental aspect of trips and how this influences the modality choice of passengers. In order to do this, a survey with special focus on the Amsterdam-Berlin and Amsterdam-London corridors is conducted. Analysis of the survey results together with help of the behavioural change matrix led to policy recommendations for governments in order to nudge passengers from air travel to the more environmentally perceived friendly high speed rail alternatives. The most important results are that people think that travelling by train is more environmentally friendly than air travel, but that people value environmental aspects of travel as not really important. Besides, people who value environmentally friendliness of a trip higher, have a higher willingness to pay for less polluting high speed rail. However, willingness to pay for the more polluting air travel is higher as well for people who value environment as more important. Furthermore, travel time is an important factor for modality choice and people tend to choose more for high speed rail when travel time is lower. Hence, when governments want to motivate people to travel by train, they should impose higher taxes on flight tickets, or subsidize high speed rail tickets. Besides, they should subsidize railway operators in order to reduce travel time of high speed rail. Different socioeconomic factors can be used to adjust policy for the right group of people. The question remains however whether travelling by train instead of plane actually helps to reduce emissions, since short-haul flights will likely be replaced by long-haul flights.

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1. Introduction

Since October 2020, a shorter and direct high speed rail connection[1] between Amsterdam and London opened with a travel time of less than four hours between the two city centres (NU.nl, 2020). This is not the only major development regarding high speed rail in the Netherlands and Europe. NS and Deutsche Bahn (the railway operators in the Netherlands and Germany) announced that they aim to reduce travel time between Berlin and Amsterdam with two hours to approximately 4.5 hours in the future. These developments could possibly help to achieve the ultimate goal for the European Union: creating a pan-European high speed rail network (NOS, 2018) (Spoorpro, 2020).

The construction of railway networks like these can be regarded as nothing more than an instrument in order to achieve bigger goals. In this case, two major goals can be identified. First, when people change from air travel to rail, there will be less demand for air travel. This will lead to CO2-emission savings, which is desirable for the requirements of the Paris Agreement (NOS.nl, 2018). Another problem in the Netherlands is the capacity problem of Schiphol Airport. The airport is now allowed to accommodate 500.000 flight movements per year at maximum, which it has nearly reached by 2019[2] (Volkskrant, 2019). A modality (mean of transport) shift would help to create capacity at the airports, which would lower the pressure on the airports. Besides, the free capacity could be filled up with the more commercially attractive intercontinental flights. It remains to be questioned whether the aforementioned improvements of the rail network will lead to a modality shift from air travel to rail for passengers and if it does, whether there will be emission savings. Besides, high speed rail would only be a serious alternative for air transport on short-haul[3] flight connections.

Governments will have an important task in reaching the goals regarding high speed rail. No private parties can afford all investments that need to be done in order to create a proper high speed rail network. Besides, governments can play an important role in promoting high speed rail to the inhabitants of the country. A tool for policymaking can be the behavioural change matrix. More on that can be found in chapter two and the conclusion.

[1] A rail connection where speeds of 200 and 250 km/h can be reached and runs significantly faster than a normal rail connection (European Commission, 2010)

[2] The flight movement data for 2020 is not representative, because of the COVID-19 pandemic, therefore, data of flight movements for 2019 is used

[3] In the case of high speed rail replacement, shorter than 700 kilometres (European Commission, 2010)

Since governments can have a major role in creating high speed rail and can influence behaviour of consumers, an important focus is on government intervention in the research question, which is formulated as:

Is government intervention needed to shift modality preference of people from airplane to high speed rail and if it is needed, what type of intervention?

Earlier research has been performed in this field. It was found that after high speed rail introduction, less seats but not always less flights are offered to consumers (Clewlow, Sussman, & Balakrishnan, 2012). Also, people will probably have more demand for trips in general when there is more supply (originating from more different alternatives) and hence, the amount of flights will not decrease that much (D'Alfonso, Jiang, & Bracaglia, 2015) or the free capacity at airports will be filled up with new flights (Socorro & Viecens, 2013). Besides, passenger demand effects after the introduction of high speed rail are already determined on national corridors in Spain (Jiménez & Betancor, 2012) and China (Zhang, Johnson, Zhao, & Nash, 2019), based on absolute data.

However, this research focuses on two international corridors: Amsterdam-Berlin and Amsterdam-London. The estimation of demand effects will be different in this research as well, using a survey, and based on willingness to pay and stated preference, with a special focus on the valuation of environmental characteristics of travelling. Lastly, this research also uses the behavioural change matrix in order to determine policy directions for governments, which is not included in other research in this field.

The remainder of this research is organised as follows. First, the literature review with an explanation of the behavioural change matrix will be given and the stakeholders in the creation of high speed rail will be identified and hypotheses will be drawn. Afterwards, the survey will be described in more detail, with an explanation of the willingness to pay and stated preference theories and the Likert scale. The used statistical methods for this research, the Kruskal-Wallis test and Jonckheere-Terpstra test, will be explained as well. In the penultimate section, the hypotheses will be tested, and in the conclusion a more detailed policy advice will be given based on the results of the analysis.

2. Literature review

Development of high speed rail connections between short-haul destinations has several implications for the parties providing transport, as well as for the passengers and governments in the countries included in the high-speed rail connection. First, some definitions will be given to delimit the scope of this research. Secondly, an explanation of the behavioural change matrix will be given, in order to give some insights in possible policies that could be imposed in order to move people towards travelling by high speed rail. Afterwards, the stakeholders, their interests, and the implications of establishing high speed rail connections will be explained. This section will be concluded by the drawing of multiple hypotheses, following the intuition of the outcomes for the stakeholders.

2.1 Behavioural Change Matrix

Governments can influence the consumption patterns of people. A tool which can be used to assess which measure is needed to adjust people's behaviour towards the socially desired optimum, is called the behavioural change matrix. This tool is designed by Fehr, Kamm & Jäger (2014). The matrix can be seen in figure 1.

Two key concepts in the behavioural change matrix are awareness and willingness to contribute. Awareness can be defined as the knowledge of an individual about how their behaviour influences other people's lives in a positive or negative manner. Sometimes people can be aware of the effects of their behaviour, but forget these effects in the heat of the moment, caused by more impulsive and faster (system one) thinking instead of slow and rational (system two). This is called a blind spot (Fehr, Kamm, & Jäger, 2014). For example: when someone is used to travel by plane to London and needs a last minute ticket, they will more often choose to go by plane instead of exploring all the different alternatives. This problem can sometimes also be solved with education and communication on the specific moment of choice of the individual. Monetary incentives are often unsuccessful in solving impulsive decisions.

In this research, awareness is defined as the perception of the extent of environmental benefits caused by travelling by high speed rail instead of airplane and how important environment is valued in choosing among different travel options. This methodology corresponds with earlier research in the field of environmental economics. Wang, Sun, Yang, & Yuan (2016) tried to measure the awareness regarding smog pollution in China and did this using a survey with five-point Likert scale questions, as did Mei, Wai, & Ahamad (2016) to measure awareness of different kinds of pollutions and climate change in Malaysia. Both researches used Likert-scales ranging from valuing problems concerning environmental damage as very serious to not serious at all. This approach will be used in this research as well. More explanation on the use of the Likert Scale in this research can be found in paragraph 3.1.3.

The second concept in the matrix is willingness to contribute. When being aware of a problem, one also has to be motivated to change behaviour in order to contribute to achieving a certain goal. An important determinant for willingness to pay is the concept of social norms, which is defined as the expectation of behaviour of the majority of a group. Thus, social norms of an individual are partly determined by direct social interactions and contacts. For more intuitive (system one) issues, people are more likely to follow the existing social norm. This can for example, in the context of this research, explain why people tend to travel by plane instead of high speed rail, although they know that travelling by rail is more environmentally friendly (Fehr, Kamm, & Jäger, 2014).

Willingness to pay for the different tickets in the survey for this research and the stated preference results will show how much people want to contribute to this case by travelling by train instead of plane. Willingness to pay makes clear which preferences people have. When varying certain travel mode characteristics, preferences for these factors will become visible based on lower or higher valuations of different alternatives. This method is used in multiple studies, for example by Jou, Chien, & Wu (2013), who investigated willingness to pay for business class seats in Taiwanese high speed rail connections by varying characteristics of the seats. Guagnano, Dietz, & Stern (1994) investigated different methods of willingness to pay concerning environmental issues. They found that willingness to pay can indeed measure preferences in social problems like environmental quality, as will be done in this research. Hence, it is expected that willingness to pay is an appropriate variable to measure willigness to contribute.

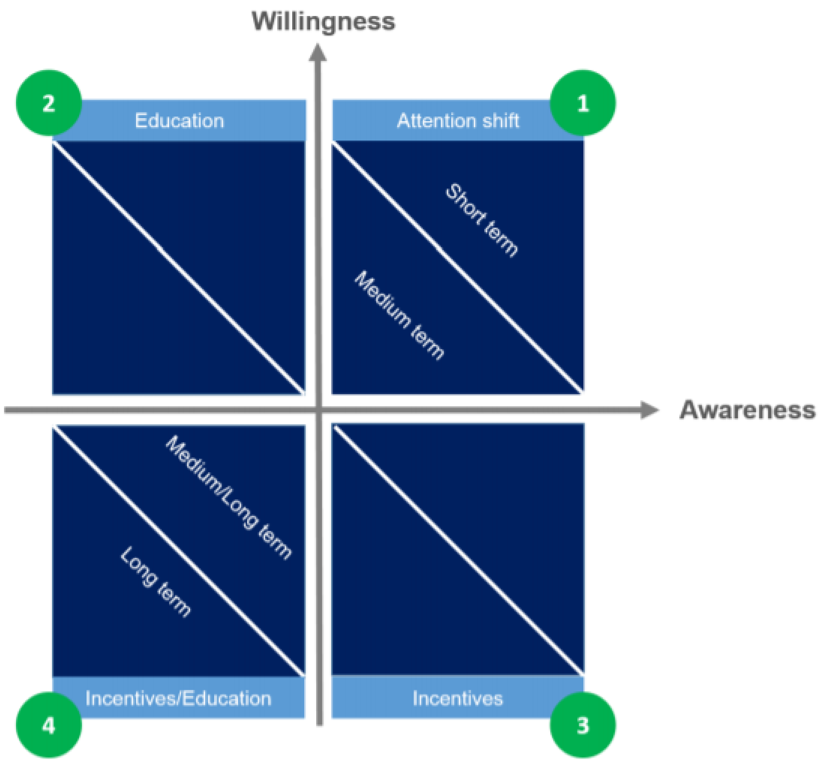
Bolis & Maggi (2003) used a stated preference method in order to measure which factors contribute to shippers' choice of transport modality. It was found that, by varying characteristics and possible changing preferences between the options, importance of characteristics can be determined.

Thus, a combination of both the willingness to pay method and the stated preference method (with actual data to simulate an actual choice for consumers) can provide important insights in consumption choices regarding transport mode. For example: when willingness to pay for train is lower than for air and the stated preference alternative of travelling by high speed rail is not often chosen, one can conclude that willingness to contribute is low and some measures should be taken to make the desired behaviour more attractive. The different measures that could be taken, are presented later in this paragraph.

Also psychological and economic costs play a role in determining whether certain behaviour will take place. When the psychological costs are higher behaviour is less common to take place. For example, when someone has to change modality often when travelling by train instead of airplane, one is less likely to choose for the train alternative. This is even the case travel time and price of the alternatives are equal. When economic costs are higher, one would expect that behaviour changes. However, since economic costs are valued in slower and more rational (system two) thinking, financial (dis)incentives might not result in the desired change in behaviour (Fehr, Kamm, & Jäger, 2014)

Figure 1.

The Behavioural Change Matrix with different policy advices and predicted time to achieve the desired behavioural change (Fehr, Kamm, & Jäger, 2014)



The factors above lead to the graph depicted in figure one, where awareness and willingness to contribute are put in a framework with relevant measures in order to improve or maintain a situation in a certain period of time. The following methods are visible (Fehr, Kamm, & Jäger, 2014):

- **Communication and education:** in order to improve awareness of positive or negative consequences of behaviour in a certain social issue.

- **Incentives:** in order to increase willingness to contribute, for example by subsidies or taxes.
- **Belief management:** in order to change social norms, and therefore to increase willingness to contribute.
- **Preference management:** in order to change social preferences, in order to increase both willingness and awareness.
- **Attention shifting** in order to influence willingness by pushing people to desired behaviour by for example nudges.

In the graphic, it can be seen that when both willingness and awareness are low, effects of measures are more likely to be noticeable in the longer term, since social norms take more time to evolve. When awareness and willingness are higher, these social norms are more present, thus resulting in a faster noticeable effect of measures (Fehr, Kamm, & Jäger, 2014).

As stated before, awareness and willingness to contribute will be measured using survey questions. When awareness and willingness to contribute are quantified, a set of proper measures will be selected using the behavioural change matrix from the measures stated above, in order to see how behaviour of people can be moved towards more usage of high speed rail.

2.2 Stakeholders

Introduction or expansion of high speed rail has implications for and is influenced by a lot of different groups and institutions. The different stakeholders in this case are listed and explained below.

2.2.1. Airports

Airports have different objectives, depending on the governance structure of the company that operates the airport. Several airport business models exist varying in the share by which the airport is owned by the government: from fully government-owned, to shared private and governmental ownership to fully privatized airports. The following governance structures can be identified (Ashford, Stanton, Moore, Coutu, & Beasly, 2013):

- **Government-owned**: in this model, the government has direct influence on daily business of the airport. When the airport is owned by the government, the main objective is trying to manage the airport in order to maximize social welfare. More on this can be found in section

2.2.2. In this structure, a further distinction can be made between different ownership forms (Ashford, Stanton, Moore, Coutu, & Beasly, 2013):

  - **Multi-level**: owned by different layers in the government. Schiphol is for example partly owned by the national government and the municipalities of Amsterdam and Rotterdam (Schiphol, 2021). By doing this, all these different stakeholders have direct influence on airport policy in order to guard their interests (Rotterdam has other interests than Amsterdam and the national government, for example lower airport noise).
  - **Publicly owned**: owned by the national government. By doing this, the national government can make sure that the airport is managed in order to maximize social welfare on the national level. An example is that the Dutch government can make sure that Schiphol contributes to reaching the Paris agreement goals.

- **Mixed ownership**: in this model, both the government and private parties have a share of the airport. The government has direct influence in order to make sure social goals are achieved, but also makes sure that the airport is managed in a commercial more optimal way. A distinction can be made in:
  - **Primarily governmentally owned airports**: the government is major shareholder in this type of airports. Hence the focus in daily operation is aimed more towards the social welfare optimum.
  - **Primarily privately owned airports**: a private party is major shareholder. These airports are managed more in order to maximize profits, but with the government making sure that social welfare issues are included in the airport policy.
- **Private ownership**: these airports often strive to maximal efficiency and are operated like any other business in order to maximize profits (Gillen, 2011). Therefore, the focus on social welfare is less apparent in this ownership structure and the government has almost no influence in policy decisions. In this structure, two types can be distinguished:
  - **Multiple stakeholder private ownership**: multiple private parties owning an airport.
  - **Private ownership**: one stakeholder which has full ownership of the airport.

Next to the government structure, a distinction can also be made on size (often determined by the number of passengers) and multimodal connections of the airport. Based on this, two types of airports can be distinguished: primary and secondary airports. Primary airports are airports with the largest share of traffic, with often intercontinental (long-haul) and continental (short-haul) connections and connections to different other modalities such as rail connections in larger urban areas. Both full service carriers and low cost carriers make use of these airports. Secondary airports on the other hand have a smaller share of traffic, with more often continental (here European, short-haul) connections, provided by more often low cost carriers and charter flights (to holiday destinations) and a limited connection to other modalities (Jimenez & Suau-Sanchez, 2020) (Lian & Ronnevik, 2011) (Dziedzic & Warnock-Smith, 2016).

Airports have become very important nodes in movement of people, which can be seen in the sharp rise in air travel during the past decades. In 2015, Schiphol Amsterdam Airport, a primary airport, welcomed nearly seventy million passengers. Nearly 70% of these passengers originated from or had a destination within Europe (Centraal Bureau voor de Statistiek, 2016). However, intercontinental passengers usually have higher expenditures at airports and hence, this group of passengers is more profitable for airports (Graham, 2009). Therefore, it is profitable for airports to increase the share of international passengers. This could simply be done by offering more slots to expand the international network. The incentives to do that are more present for privately owned airports. However, many airports are facing capacity constraints that hinder airports in increasing its capacity, which are often imposed by governments. Schiphol Airport (governmentally owned) is one example of an airport facing constraints like these, namely a maximum of 500.000 flight movements per year. In order to still enable growth of the number of intercontinental flights, Schiphol and the Dutch government aim at the construction of Lelystad Airport, which will open in November 2021 and will accommodate 20.000 flight movements on a yearly basis, which will mainly contain (holiday) charter flights (Schiphol Airport, 2020). It is important though for Schiphol (and other airports of course) to continue European flights, since this (next to local passengers with a European destination) might attract passengers from other continents to book indirect flights via Schiphol to their final destination, because of financial reasons. A complete network is therefore essential for international airports (Redondi, Malighetti, & Paleari, 2011). This can also be achieved by offering high speed rail connections.

Another strategy is to create room for more intercontinental flights to depart and arrive and decrease the airport congestion. Congestion here means that the use of a time slot by an aircraft prevents the usage of the timeslot by other airlines. It can also cause delays for other aircrafts at the same time slot (Levine, 2009)) resulting from the capacity constraints, could be the substitution of short-haul flights by high speed rail. For Schiphol this could for example mean that the number of departures towards Paris, London and Berlin can be decreased. On weekdays, thirteen direct flights originating at Schiphol towards Berlin, 25 direct flights to Paris and nearly 60 direct departures towards London take place (Skyscanner, 2020). On a yearly basis this adds up to more than 60.000 flight movements to cities on which high speed rail competition is already present or advanced plans for the start-up of a high speed rail network do exist. The first applies to London and Paris, the latter to Berlin. In total, these flights amount to 10 percent of the total number of flights at the airport. Thus, development of high speed rail connections as a substitute for these short-haul flights could potentially reduce congestion and increase possibilities for other connections to be introduced, in order to increase profits.

The amount of flights movements per year could, In the case of Schiphol, be increased up to the cap 500.000 movements as mentioned above. With the reduced amount of short-haul flights, the already desired expansion of international flights could be done with little additional negative externalities for the surroundings of the airport, a second possible advantage of the introduction of high speed rail (Janic, True Multimodalism for Mitigating Airport Congestion, 2010) (Clewlow, Sussman, & Balakrishnan, 2012) . These externalities have mainly to do with air pollution and aircraft noise (Royal Schiphol Group NV, 2018). Externalities are an important factor when considering social welfare airport operations bring to society. More elaboration on this topic can be found in section 2.2.2.

In the case described above, high speed rail offers a direct connection between two cities (e.g. Amsterdam and London). This reliefs the infrastructure and might decrease pollution and noise at the airport as previously mentioned, but these benefits can be achieved to a higher extent when vertical collaboration between the airport and high speed rail provider takes place by means of a direct connection of the airport to the network. In this case, the rail connection can become a feeder service for international flights and passengers do not face the inconvenience of using an extra transport mode to change from plane to high speed rail or vice versa. This, together with an expected decrease of congestion and hence delays, will result in significant time savings for the passenger and hence a better competitive position of the airport (Janic, True Multimodalism for Mitigating Airport Congestion, 2010) and could ultimately lead to more earnings for the airport (Takebayashi, 2016) (Xia & Zhang, 2017).

However, for all these benefits for the airport to be achieved, certain conditions have to be met. It depends on the size and type of operations of the airport to what extent these benefits will be present. For example: a charter flight oriented airport provides services to customers who are not interested in intermodal solutions. The list of the conditions for suitable airports (for example with a high share of business passengers or connections to multiple big cities) for high speed rail is listed below (Clewlow, Sussman, & Balakrishnan, 2012) (Janic, True Multimodalism for Mitigating Airport Congestion, 2010):

- The airport has to be connected to the high speed rail network and the airport should have a rail station with enough capacity to accommodate all passengers. Otherwise, people might still prefer short-haul flights over the train.
- Scheduling of high speed rail and flights need to be linked to each other. Long waiting times decreases attractivity of the airport and rail as a transport mode.
- Frequency needs to be adapted to total demand to ensure that rail provides enough substitutive capacity for the passengers.

As stated above, the benefits to be obtained depend on the type and size of airport. Since these conditions require significant investments to be made, a proper analysis of the potential benefits and costs of introducing high speed rail to the airport has to be done.

Also, the financial impacts for non-HSR-suitable airports have to be considered (by for example the government, see section 2.2.2), because implications of high speed rail development for secondary airports might be very different compared to primary airports. Zhang, Graham, & Chun Wong (2018) found that benefits (in the form of for example extra available time slots) for secondary airports are much more limited. Connections to high speed rail networks are difficult for these airports. Besides, an important part of the flight movements at secondary airports are short-haul flights, for which high speed rail will be a substitute. Traffic at these airports might therefore decrease, depending on the reaction of passengers and low cost carriers on the introduction of high speed rail networks. This is in line with the findings earlier in this paragraph (Jimenez & Suau-Sanchez, 2020) (Lian & Ronnevik, 2011) (Dziedzic & Warnock-Smith, 2016).

2.2.2. Government

Since air and rail transport may bring many positive and negative externalities to the society and firms do not always have the incentive to behave according to the social optimum, the government often intervenes in these markets. The goal of the government in this case is assumed to be the maximization of social welfare in the country (Davis & Whinston, 1962). An example of this is the previously mentioned yearly flight movement cap of 500.000 present at Schiphol Airport, where the government seeks balance between the interests of the airlines and people living near the airport site.

In order to analyse the motivations of the government in this case, the externalities coming from airport operations and railway operations have to be listed. Governments face a trade-off between the positive impact of an increase in airport activity on for example employment and the negative environmental impacts of the increase in activity.

As discussed in section 2.2.1., the development of high speed rail may lead to increased connection at an airport, both for high speed rail and air transport. This increased connection may lead to several positive welfare effects. First, there is the direct effect of increased operations at the airport, which contains an increase of the gross domestic product due to the increase in employment at facilities at the airport itself. Then, there is also an indirect effect. Suppliers of airport facilities also experience an increase in operations, caused by the increase in operations for the airport, which brings additional employment as well. The additional direct and indirect employment causes extra expenditures by the newly employed people in a variety of sectors, which multiplies the employment effect of increased airport activity. Lastly, the presence of an airport increases connectivity for a region. This results in increased attractiveness of the region for foreign direct investments and may affect location decisions of companies in a positive manner for the region, since companies are more likely to choose a location where connectivity is good and other comparable or complementary companies are present (Decisio, 2015) (InterVISTAS, 2015) (Ivy, Fik, & Malecki, 1995) (Janic, 2016).

As stated in section 2.2.1., aircraft operation is accompanied by negative externalities, the most important being noise and pollution (Royal Schiphol Group NV, 2018). When substituting short-haul flights with high speed rail, the noise and pollution of caused by aircrafts will decrease, ceteris paribus. Janic (2003) found that environmental performance of high speed rail is better compared to air passenger transport, and that substitution of air transport by high speed rail would lead to less cumulative environmental damage. This is confirmed by Zanin, Herranz, & Ladousse (2012), who studied the impacts of high speed rail introduction on emissions at Madrid Barajas Airport. They found that the introduction of high speed rail led to a reduced amount of people travelling by plane or private car, which decreased emissions on the corridor. Also, the noise level produced by high speed trains is perceived less annoying than aircraft noise (Elmenhorst, et al., 2012).

The environmental benefits regarding emissions are however debatable. As described in section 2.2.1., the short-haul flights (when redundant) are likely to be replaced with longer flights, which are often carried out by bigger and more polluting aircrafts. It is also questionable whether high speed rail will fully substitute short-haul flights. In cross-border markets where high speed rail is already available for a longer period of time, for example London-Paris, high speed rail is dominant, but does not capture the full market and flights on the corridor are still offered. On new corridors, the substitution of short-haul flights by high speed rail will be modest, based on results in the past (Givoni & Dobruszkes, 2016). Hence, the decrease of emissions will only be modest as well. D'Alfonso, Jiang, & Bracaglia (2015) even find that the introduction of high speed rail might worsen the environment, caused by the traffic generation effect: more supply results in more demand. Governments can decrease this effect by creating awareness for this problem or by using financial incentives. This may take a lot of time. Therefore, both high speed rail and air services will remain existent. Socorro & Viecens (2013) agree with that, adding that especially at airports with a flight cap will experience a net increase in the amount of trips, because the available number of movements due to reduction of short-haul flights (substituted by high speed rail) will incentivise airlines to introduce new connections.

Governments have to consider and assess all possible effects of introducing high speed rail in order to come to the socially desirable solution. When a government ultimately decides to construct a high speed rail network, a substantial investment should be made by the government, since private parties will likely underinvest for the amount of possible positive externalities resulting from the project (Gillingham & Sweeney, 2010). Also, different European governments have to cooperate in order to streamline the process and create one optimal connected network, since this network is not present now and is essential for fast and efficient rail operations (Preston, 2013). The European Union has an important role in the creation of the network, since it has impact on entire Europe. The EU finances a huge part of the creation of high speed rail networks (infrastructure and stations) across Europe and facilitates cooperation between the national governments, airports, railway operators and airlines (European Commission, 2010).

Next to direct investments, the government has to invest in programmes or incentives in order to influence the behaviour of the population, on which more theory can be found in paragraph 2.1. Examples can be higher flight ticket prices by imposing taxes, which happens in The Netherlands since the beginning of 2021 (Rijksoverheid, 2021), subsidizing high speed rail tickets and making people aware of the problem by using advertisements or setting up a European campaign (European Commission, 2010).

Governments can also reconsider the channels in order to implement policies. When airports are privately owned, governments can buy airports in order to have direct influence on the daily business of the airport to decrease the negative externalities originating from airport operations, as is explained in 2.2.1.

2.2.3. Passengers

Passengers will also experience major changes after introduction of high speed rail. As said earlier, passengers will have one additional mode to consider when making mode choice for the desired trip. Several factors determine the attractiveness of a certain travel mode: the travel mode characteristics. These characteristics are the following (Yang, Wang, Liu, & Zhou, 2018) (Bhat, 1998):

- Price: people tend to prefer the alternative with the lowest costs when quality of the trip is comparable (Qin, Chen, Cu, & Wang, 2014). This is confirmed by a research performed by the International Air Transport Association (IATA), where they found that price is the most important determinant for people in order to choose among different flight alternatives (IATA, 2015). It is found in this research that train tickets tend to have a higher price than flight tickets (NS International, 2020) (Skyscanner, 2020). However, as is stated in this paragraph, people prefer the cheapest alternative when quality is comparable. Thus, it is important to note that people always make a trade-off between price and other factors determining modality choice.

- Travel time: people prefer the alternative with the shortest travel time, when other factors contributing to trip characteristics are comparable (Qin, Chen, Cu, & Wang, 2014). This is based on the theory that people have a fixed daily time budget (which is of course equal to 24 hours a day). When spending time travelling, this time cannot be used for other purposes which are perceived as more useful or are experienced as more relaxing. For leisure activities, the willingness to pay for time savings is usually lower than for business trips, as for the latter useful productive time decreases when a trip is longer (Steck, Kolarova, Bahamonde-Birke, Trommer, & Lenz, 2018). In this case, travel time is more than in-vehicle time alone. In this research, in order to determine people's willingness to pay for certain trips other components in the total travel time are added. An overarching term for this is out of vehicle time, which is for example the check-in, customs or boarding process at the airport. Waiting time at the terminal and walking to the gates are also added to the total travel time, with for the flight and bus alternatives also the travel time after arrival at the flight/bus destination to the city centre added to the total travel time (Limtanakool, Dijst, & Schwanen, 2006). Therefore, a flight from Amsterdam to London lasts approximately five hours in this research, while the flight itself lasts for approximately one hour (Skyscanner, 2020).
- Comfort and safety: the quality of seats, personal space of the seats, the number of times that people need to change in combination with an affordable price. People prefer to travel with a modality where resting, working, moving around or enjoying certain forms of entertainment are possible. Passengers also prefer to travel in a non-noisy environment. Since the train is often more silent and has more space than an airplane, one can expect that passengers for which comfort is important, prefer to choose for the train alternative (Johansson, Heldt, & Johansson, 2006)
- Flexibility/convenience: the higher the frequency of a mode, the more flexibility it offers, the more attractive the alternative appears to passengers. This is related to the convenience of travel: an alternative with high frequency, but with two transfers in the trip, will come out worse in the valuation of people. The earlier mentioned report of IATA found corresponding results. They found that frequent and convenient flight times with less transfers lead to a higher preference for people for a certain flight (IATA, 2015). Hence, it is important as airline or train company to offer frequency at the desired times. It is important to note that people experience higher flexibility when multiple new modalities and time slots are offered. This can

lead to an increased demand for a trip on a certain corridor (ceteris paribus) than before introduction of these extra options, the so-called traffic generation effect, as is mentioned in paragraph 2.2.2. (D'Alfonso, Jiang, & Bracaglia, 2015).

- Environmental characteristics: subjective attitudes and perceptions, for example about environmental impacts of a certain travel mode, may influence the valuation of that certain mode and change the view of the other characteristics. This is also found by Johansson, Heldt, & Johansson (2006). When people generally think to have an environmentally friendly lifestyle and prioritize environment in more product choices, they are likely to also to take environmental characteristics into account when making a modality choice. However, Johansson, Heldt & Johansson (2006) also found that environmentally friendly behaviour only takes place when it is easy to perform. Therefore, it is debatable how big the effect of environmental aspects will be, or whether other characteristics in this list are more important in modality choice. This will be found out in this research. How the perceived importance of environmental factors is determined in this research can be found in paragraph 2.1 and in chapter 3.

The main focus of this paper are the characteristics concerning travel time, price and environmental aspects, as said earlier in this paragraph.

In the list of factors contributing to mode choice above, travel time is an important characteristic. The fact that passengers tend to choose for the alternative with the least travel time (other factors being equal among the alternatives) because of their fixed time budget, leads in this research to the following hypothesis:

Hypothesis 1: *willingness to pay for an alternative is higher for alternatives with lower travel time, irrespective of the travel mode.*

As stated before, travel time is in this research determined by in-vehicle time and out of vehicle time. The data used for the questionnaire is further explained in chapter 3.

The last point in the list above indicates that norms of a certain individual may change the utility an individual gets from a certain combination of factors for the trip, which may influence willingness to pay dramatically. For example, when an individual values environmental impact as very important, travel time and comfort may be valued completely different. People may value the alternative they perceive as most environmentally friendly the highest. In various researches, train is perceived as an environmentally friendly modality compared to airplane (Johansson, Heldt, & Johansson, 2006) (European Commission, 2010) (Yang, Wang, Liu, & Zhou, 2018). Hence, in the rational approach, environmentally friendliness increases utility, thus willingness to pay for a modality and in reverse, environmentally unfriendly modalities decrease utility and hence willingness to pay for this modality. Therefore, the following is hypothesized:

Hypothesis 2: *willingness to pay for train is higher for people who value environmental characteristics as more important.*

Hypothesis 3: *willingness to pay for air transport is lower for people who value environmental characteristics as more important.*

It is however the question how many people actually value train relatively higher compared to air transport based on environmental impacts. An important factor next to awareness of the problem (in this case, the pollution that is caused by air transport compared to the more environmentally friendly train) is the belief that a certain measure could help in solving the problem. In this case, passengers should be convinced of the fact that travelling by high speed rail instead of airplane contributes positively to the environment. A survey conducted in China, a country with many high-speed rail connections, pointed out that a majority of people belief that high speed rail will lead to environmental benefits (He, Mol, Zhang, & Lu, 2015). Therefore, the following is hypothesized:

Hypothesis 4: *a majority of people thinks that travelling by high speed rail instead of travelling by plane is environmentally beneficial.*

Beliefs of people change over the years. This can for example be caused by a different social environment and more income. For example, students have lower expenditures and willingness to pay, simply because they often have less money to spend. Therefore, it can be assumed that people have a higher willingness to pay when getting older and tend to choose for a more comfortable (or time-saving) option, although it is more expensive (Mitchell & Carson, 1989) (Harvey, Thorpe, Caygill, & Namdeo, 2014). Besides, social norms are subject to change over time. When people become older, they interact with different people, have other life circumstances and a different socioeconomic environment. Social norms are partly based by culture, interaction and social life; therefore, norms are also likely to change when becoming older. Hence, people value characteristics differently at different ages (McDonald & Crandall, 2015). Therefore, the following can be hypothesized.

Hypothesis 5: *willingness to pay is positively correlated with age and the stated preference points less towards the low cost alternative when age is higher.*

In this report, a survey will determine the results for the hypotheses listed above. More on this will be explained in chapter 3.

2.2.4. Railway operators and rail maintenance companies

The construction of high speed rail networks requires major investments. As said in section 2.3.2., the government may be involved in the investments regarding the construction of the network. Since the government may not have sufficient funds to fully finance the network, involvement of private parties is required, although these may be discouraged by the significant infrastructure investments which are often required in projects like these. Cooperation between the various national governments and private railway companies are required to successfully introduce high speed rail on the continent. Often, the railway companies are partly private and governmentally owned (Roll & Verbeke, 1998).

The railway infrastructure companies in several countries have to invest in sufficient electrification systems and European-wide standard track gauges, which can lead to speed increases (Lindahl, 2001). European railway operators have to cooperate as well, and have to invest in vehicles which are suitable for higher speeds and in infrastructure at the stations or the construction of new corridors, corridors to existing stations or the construction of new stations. The first important goal is to create a high speed rail network in Europe with universal technological standards, so that the speeds of 200 and 250 km/h can be reached and that no stops are needed at country borders (European Commission, 2010).

In The Netherlands ProRail is an example of a company which is a European leader in the development of short-haul high speed rail networks. According to ProRail, the development of a high speed rail network can lead to significant emission savings (ProRail, 2021). The European Union supports this initiative and provides funds in order to improve the network, in order to create a pan-European fast transport network called the Trans-European Transport Network (TEN-T), in which the high speed rail network is only a small part. Completion of the network is planned for 2030. The countries included in this research (The Netherlands, Belgium, Germany, France and the United Kingdom) are all close to completion of their part in the network (European Commission, 2021). National railway maintenance organisations have to contribute as well in order to complete this network.

Before making the investments both the railway operators and the railway infrastructure companies have to make well-funded considerations regarding the expected demand and growth. Then, the network is future proof. Collaboration between railway operators, airports and airlines can result in extra demand for the high speed rail network, because passengers of intercontinental flights can travel by train to other destinations on the continent (Xia & Zhang, 2017) (Socorro & Viecens, 2013). Cooperation is therefore highly recommended. This is underlined by a statement of ProRail, the Dutch railway maintenance agency (ProRail, 2021) and is supported by the European Union (European Commission, 2010).

The international railway market is liberated in 2010. Therefore it is possible for different railway operators to compete for concessions on certain international corridors. This will benefit the passenger, since optimal quality and a fair price is the expected result of this competition (European Commission, 2010). Rail operators also have to invest in commercial expansion of the networks, in order to attract passengers to use their mode of transport.

Due to the liberation of the international railway market, different international players are active on international corridors in The Netherlands: Eurostar on the Amsterdam-London corridor, Thalys on Amsterdam-Paris, NS International to Berlin (and other German destinations) and Brussels, and Deutsche Bahn to Berlin and various other destinations. Competition on one specific corridor is currently not present in the market for passengers (European Commission, 2010). This competition takes place on beforehand when corridors are allocated to companies. On these corridors, companies are monopolists for a certain period of time, until the next concessions are determined (Martin, 2002). Different companies participate in concessions for different international corridors.

However, this might change in the foreseeable future. International bus transfer company Flixbus started a sister-company called Flixtrain, aiming to introduce intercity trains between various international destinations as a faster alternative for Flixbus. Flixtrain for example plans to request permission to operate seven daily trips on the corridor from Amsterdam to Paris, which is now operated by Thalys (Treinreiziger.nl, 2019). This increase in competition and possibilities to lose corridors after the current period of the concessions lead to the fact that rail operators are forced all the time to strive for competitive prices and maximum quality of the service in the form of on time performance, comfort in the train and capacity. This all benefits the passenger.

Due the COVID-19 pandemic, different international airlines had to give up timeslots (Parool, 2021). Modalities are less attractive when frequency is lower (IATA, 2015), hence demand for air travel may decrease which can benefit the train. However, the effect of the pandemic might be ambiguous, since also less people are expected to travel in general, hence leading to less aggregate demand for transport and hence, possibly also for train.

2.2.5. Airlines

Airlines may face fierce competition of high speed rail, which may have major implications for the profitability and network of the carrier. These implications depend on the decrease of market share on the corridor after the introduction of high speed rail. Airlines may opt to leave trunk routes[4] and aim more to regional connections, creating a hub and spoke network, or can invest more in intercontinental flights (Jiang & Zhang, 2016). This can be the case for full service carriers, often being airlines having intercontinental destinations. For low cost carriers, these effects may be different, since those airlines already connect secondary (regional) airports and often operate continental, and therefore likewise not expanding operations intercontinentally.

When working together with airports and railway companies, a more intercontinental network may be very profitable for full service airlines, since both services can be adjusted to each other and therefore be very attractive to potential customers. The airport can then be used as a multimodal hub with a smooth air rail connection (Albalate, Bel, & Fageda, 2015) (Clewlow, Sussman, & Balakrishnan, 2012) (European Commission, 2010).

Airlines can also change frequency on existing networks. Zhang et. al (2019) found that domestic airline frequency in China decreases with 60% when high speed rail competition exists on the corridor. A decrease of domestic aircraft operations on routes with high speed rail competition can also be seen in Spain, although the decrease is less extensive (Jiménez & Betancor, 2012). Simply decreasing frequency on a corridor where competition is present may however not be the best strategy, since a higher frequency also can attract more passengers to a certain transport mode, as stated in section 2.3.3. (Bhat, 1998) (Yang, Wang, Liu, & Zhou, 2018). Some airlines therefore choose to increase frequency, but operate smaller aircrafts, aiming at a higher load factor[5] per aircraft, which may result in a higher margin per passenger (Dobruszkes, 2011). Albalate, Bel, & Fageda (2015) find as well that airlines do not decrease frequency in order to stay competitive, but choose to decrease the amount of seats to lower costs. Airlines do this by operating smaller aircrafts, which have lower maintenance and fuel costs.

As stated earlier, the business models for low cost carriers and full service carriers are different. Therefore, the implications for low cost carriers will be different than those of full service carriers, as is for strategic reactions. Since low cost carriers often have a fleet containing only one aircraft type to keep maintenance costs as low as possible, seat reduction is not likely to happen, since this requires

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[4] Routes connecting larger cities within a country or several countries

[5] Load factor: number of passengers relative to total capacity

huge investments in new aircrafts (De Wit & Zuidberg, 2012). In order to stay competitive, frequency is also not likely to decrease, following the logic of Dobruszkes (2011) and Albalate, Bel, & Fageda, (2015). Low-cost carriers most often operate at a continental level and will therefore also not leave corridors in order to enter new intercontinental markets. Therefore, one may expect no changes in the operations of low-cost carriers, except for the fact that an airline can decide to withdraw completely from a certain route or faces bankruptcy.

Since price is an important factor in the choice of modality for passengers (Qin, Chen, Cu, & Wang, 2014) (IATA, 2015), the market perspectives for low cost carriers might not change that much either. Prices for low cost carriers are often much lower than prices for high speed rail (Skyscanner, 2020) (NS International, 2020). This can be validated by using the stated preference method in the survey (which will be explained more extensively in section 3) and willingness to pay. It is important to note that travel time must not differ too much from the other alternatives. For example, Flixbus may be cheaper, but travel time is sometimes more than two times longer than travelling by airplane or train. However, the fact that price is one of the most important factors leads to the following hypothesis:

Hypothesis 6: *demand for low-cost air travel remains approximately constant after high speed rail introduction, because passengers generally prefer the alternative with the lowest price.*

One important assumption for this hypothesis is that prices of low cost air travel stays constant, or in any case lower than the alternatives. The question is however whether this is still the case in the future. The Dutch government recently imposed a tax on flight tickets (Rijksoverheid, 2021) and many political parties aim to impose higher taxes for the air transport sector (Trouw, 2021). Besides, multiple countries asked the European Union in 2019 to levy European Flight taxes instead of their own tax policies (Rijksoverheid, 2019). These were not imposed on the first occasion, but this might still happen in the future. All these taxes may lead to lower attractivity of air transport tickets; hence demand will be lower. When demand is lower, this can have major consequences for the financial position of airlines. Strategy changes as discussed above (by withdrawing from corridors, enter new corridors or change the business model from continental to intercontinental) have to be examined by the industry, in order to stay competitive in the future.

An additional effect may come from the COVID-19 pandemic. KLM and Lufthansa needed major state aid in order to be able to survive the crisis. However, in exchange for this aid, the airlines had to give up different time slots for ecological reasons (Parool, 2021). Modalities are usually less attractive when frequency decreases (IATA, 2015), hence less people may travel with airlines after the crisis and prefer the train. Besides, less business passengers are expected, which also decreases demand for the service.

3. Methodology and data

In order to test for the hypotheses listed in chapter 2, a survey is conducted. This survey will make use of the willingness to pay theory, stated preference and Likert scales in order to test for preferences of passengers. More explanation about the survey and methods used can be found below.

3.1 Survey description

A survey is conducted in order to find the preferences of passengers regarding the different transport modes. The survey can be found in Appendix 1. The survey is web-based for fast and many responses, created with Qualtrics and distributed via Facebook, WhatsApp and LinkedIn. Before distribution, the survey is revised by the supervisor of this research and five independent people on clear formulation, terminology and survey flow.

First, socio-economic characteristics like gender, age and occupation are asked to make a distinction between factors that can possibly influence preferences. Afterwards, opinions are asked on alternatives for travelling by plane, train and bus to London and Berlin, originating from Amsterdam. These different modalities are chosen in order to find the environmental preferences of passengers, since rail options are often perceived as more environmentally friendly (He, Mol, Zhang, & Lu, 2015) than air alternatives. By asking comparable trips regarding travel time, the environmental aspect in the modality choice may become visible.

The destinations are chosen based on the fact that on the Amsterdam – London route a high speed rail connection recently opened, and for Amsterdam-Berlin route plans for a faster connection do exist which will result in a travel time reduction of 45 and ultimately 120 minutes (NOS, 2018) (Spoorpro, 2020). The influence of this shorter travel time on the transport mode choice of passengers will be examined in this survey. In order to examine willingness to pay variations for different travel times in more detail, Flixbus alternatives are included. This is done because travel time for bus trips are significantly longer, hence preferences may be clearer.

Travel time is included with both in-vehicle time and out of vehicle time. This includes the check-in process and for the Flixbus and air alternatives transport to the city centre, which is assumed to be equal to the ultimate destinations of the rail corridors: London St. Pancras International and Berlin

Hauptbahnhof. Travel times from the airport and Flixbus destinations to these stations are determined by information of the local public transport providers (Berliner Verkehrsbetriebe, 2020) (Transport for London, 2020). For the duration of the check-in process at the airports, the average check-in time is retrieved from Schiphol, which is approximately two hours (Schiphol, 2021). The flight duration is retrieved from Skyscanner (2020) For the train alternatives, half an hour check-in time is assumed based on information of NS International (2020), together with the travel times to Berlin. Travel time to London is retrieved from Eurostar (2020). Travel time from the buses and check-in time is retrieved from Flixbus (2020). In the alternatives for Berlin, future improvements of the Amsterdam-Berlin corridor are included. By doing this, it can be determined whether measures regarding travel time reduction will be effective to make high speed rail more attractive. Thus, policy recommendations can be made based on this knowledge. The travel times after improvements are based on various news articles (NOS, 2018) (Spoorpro, 2020). The improvements will happen in two stages: first travel time will be reduced with 45 minutes, later it will be reduced with an additional 75 minutes which results in a total two hour time savings compared to the current situation.

After the willingness to pay parts, preferences are tested using the stated preference method, which will be explained in depth below. In these questions travel time as well as origin and destination of trips are used, together with prices of the modalities, which are retrieved from the specific transport provider (Eurostar, 2020) (Flixbus, 2020) (NS International, 2020) (Skyscanner, 2020). Afterwards, attitudes towards different transport mode characteristics are asked using a Likert scale format, which will be explained in more depth. At the end of the survey, participants will be asked to rank price, travel time and environmental factors based on their valued importance and whether they believe travelling by train is actual beneficial for the environment or not. The impact of these choices on the preferences of passengers will be evaluated.

Several earlier mentioned methods are applied in order to find the preferences of passengers. These methods will be explained below.

3.1.1. Willingness to pay estimation

In the first part of the survey, consumer preferences will be investigated using the willingness to pay of individuals. The willingness to pay is the (maximum) amount of money an individual wants to pay for a certain product (Hanemann, 1991). The method used in this research is the so-called direct method, where participants are directly asked their valuation of a certain product based on a description (Breidert, Hahsler, & Reutterer, 2006). In the description, characteristics like departure station, travel time including boarding process and modality are included. Insights in this willingness to pay will identify how passengers value the different modality characteristics, for example by analysing willingness to pay for longer or shorter duration of trips and for different perceived environmental characteristics. This valuation of characteristics can be interpreted as willingness to contribute to emission savings, on which more explanation can be found in paragraph 2.1. This willingness to contribute can lead to policy recommendations by using the behavioural change matrix. For more details on the willingness to pay questions, see appendix 1.

This method has several potential pitfalls. A bias is likely to occur, because participants tend to focus too much on price when directly asked for a valuation of a product. Besides, people value products differently in an experimental context compared to real purchasing behaviour and the good may be too difficult for people to value (especially the train, which is a relatively new product) (Breidert, Hahsler, & Reutterer, 2006).

In this context, these biases might not be a huge problem, since the main focus is the relative valuation of the alternatives compared to each other. When an individual behaves rationally, it is likely that this individual over- or undervalues the alternatives consistently. The pattern of the valuations might still give useful insights in this case. Besides, by asking valuations on two different corridors, a control mechanism is in place for possible errors, especially since the London corridor is more known by passengers.

3.1.2. Stated preference

Another method applied in this research is stated preference. Individuals can choose among different alternatives, with all the necessary information provided (Hess, Adler, & Polak, 2007). The goal of this approach is to simulate research in a revealed preference context. Actual data of the alternatives is presented, together with the price of the alternative, which is the major difference compared to the willingness to pay method. By comparing the willingness to pay for the alternatives with the choice in the stated preference question, the importance of price for the participant can be estimated in practice and importance of the other characteristics can be revised.

The stated preference method can be used in order to determine which characteristics of a transport trip contribute stronger and less strong to the utility function of the trip and which variations lead to other choices. Based on this, policies can be developed to make the modality more attractive. There is one important pitfall in using the stated preference method: people may in reality not act as they say in a research environment. This can lead to different misunderstandings and changes that do not improve the modality (Kroes & Sheldon, 1988).

In this case, the stated preference is connected to willingness to contribute. When people change preferences because of environmental characteristics in the form of less emissions of a certain modality, one could interpret this as willingness to contribute to the context of this research. More explanation on this matter can be found in paragraph 2.1.

The information on prices and other travel characteristics is based on retrieved information on websites of the different modalities in June 2020 (NS International, 2020) (Flixbus, 2020) (Eurostar, 2020) (Skyscanner, 2020). Information of the hypothetical faster ICE scenario is based on news articles (NOS, 2018). The price of the faster ICE is based on the current price. A price increase of nearly 30% is assumed for the 30% time savings of the modality and rounded to 49 euros because of psychological pricing as often happens for ticketing.

3.1.3. Likert scale

Multiple questions about attitude towards certain characteristics of travel modes are included in the survey (Joshi, Kale, Chandel, & Pal, 2015). The Likert Scale is useful in these kinds of questions. Participants will face a couple of statements on which they can show their level of agreement. This will show the specific attitude of participants towards the issue.

In this research, a five point Likert scale is used. Participants can choose the following alternatives: strongly disagree, disagree, neutral, agree and strongly agree. The specific characteristics are sorted randomly (so, the order of the questions will vary for every participant in order to avoid biases). The scale is used to measure passengers' attitude towards importance of environment, price and travel time in trips and the belief in high speed rail as a solution for the emission problem. The data retrieved from the Likert Scale can be ranked based on level of agreement. Hence, the data is ordinal with 5 being equal to strongly agree and 1 to strongly disagree.

One pitfall is that distance between the different ranks cannot be measured. Hence, there might be a bias in the causal relationships that are found in the research. Since the data is ranked and intervals between individuals filling out the survey are possibly not equal, a standard parametric test cannot be used. This is because the data is not normally distributed (or distributed in another way). Another reason is that the data sample is relatively small and is skewed (as can be seen in paragraph 3.3 on descriptive statistics) (Grech & Calleja, 2018). Because of this, non-parametric tests are applied to analyse the data: the Kruskal-Wallis H-test and the Jonckheere-Terpstra test. More explanation on these tests can be found in paragraph 3.2.

3.1.4. Data conversion

The data is split into two separate data sets for the results of the Berlin corridor and the London corridor. For both data sets, the data is converted in order to make it usable for statistical analysis. Gender is converted into a binary variable, with 1 being equal to male and 0 to female. Further transformations are done in the stated preference questions. For all answers to these questions a separate binary variable is created with 1 being equal to yes (when an alternative is chosen) and 0 to no (when an alternative is not chosen). The same strategy is used for the main occupations. For example: when someone works full time, the value for this variable is 1. When someone is student, the value for 'Full time employed' is 0.

The Likert questions are transformed in ranks, with 1 (the lowest) being equal to not important and 5 to very important. For example, if someone has a strong environmental attitude, the answer might be that environmental factors are very important for modality choice. This individual is then categorized as 5, together with other people with strong environmental preferences. The influence of this rank is then used to measure influence on willingness to pay in order to measure whether this environmental attitude results in different consumption patterns.

3.2 Statistical analysis of survey data

Different statistical methods are applied in this research to find patterns in the data. To do this, the statistical program STATA is used with a special module for the Jonckheere-Terpstra test. The methods applied in this research are explained below.

3.2.1. Kruskal-Wallis H-test

The first test used in this research is the Kruskal Wallis H-test. This test tests whether there exist differences between different population groups. This method is applied in various other scientific publications. Smith & Mathias (2010) tested whether the amount of studied years influenced opinions about learning methods and thereby categorized students in different groups, based on their study years. Besides, Harpe (2015) states that the Kruskal-Wallis can also be used for analysis where groups are split and ranked using Likert Scale answers, as is done in this research. Here, groups are splitted and ranked based on their environmental preferences, as is explained in paragraph 3.1.4.

The null hypothesis of the Kruskal-Wallis test states that the population groups are identical and hence have the same distribution. This is expressed mathematically in the hypothesis that the medians of the samples are the same, although this does not necessarily mean that the entire distribution is the same. The formula for the test statistic H is as follows (Van Hecke, 2012):

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1), \quad N = \sum_{i=1}^{k} n_i$$

Where:

n_i = number of observations in group i

N = number of observations for all groups

R_i = sum of the ranks for each group i

k = number of groups in total sample

In order to run the test, first the data for all groups should be ranked in ascending order and ranks should be given to the data points. For each different group i, the sum of all the ranks should be computed. Then, the test statistic can be calculated as in the formula above. Then, H can be compared to the critical chi-square value corresponding with the degrees of freedom of the sample, which is the amount of groups k minus 1, so in this paper 5 – 1 = 4. H can also be compared with the desired significance level. When H is higher than the critical chi-square value, the null-hypothesis can be rejected and there exist differences in distribution between groups. Alternatively, the null-hypothesis cannot be rejected, which implicates that no significant differences exist between groups within the sample (Van Hecke, 2012).

3.2.2. Jonckheere-Terpstra test

In addition to the Kruskal-Wallis H-test, the Jonckheere-Terpstra tests not only whether there exist differences between different population groups, but also in which order the differences between groups in the total sample appear. Smith & Mathias (2010) did this in the earlier mentioned research of study years and attitudes to learning methods. They wanted to test whether attitudes towards methods became more or less positive when students already studied for a longer time. The Kruskal-Wallis test only displayed the information that there existed differences between groups. The Jonckheere-Terpstra test added the order in which groups had more positive opinions than others. Ali et al. (2015) used the test in order to do bacterial counts for different cleaning methods and wanted to test in which order the cleaning methods where most and least effective. In this research, groups are ordered based on environmental preferences, as is explained in 3.1.4. The relationship between these groups and their willingness to pay will be analyzed, as is explained in chapter four. The Jonckheere-Terpstra test will give more information about the order in which willingness to pay differs among the groups.

The alternative hypothesis of the Jonckheere-Terpstra test is that distribution η of groups differ in a certain order, which can for example be shown as $\eta_1 \leq \eta_1 \leq \ldots \leq \eta_K$ or $\eta_1 \geq \eta_1 \geq \ldots \geq \eta_K$. The test statistic for the Jonckheere-Terpstra Test is computed as follows (Ali, et al., 2015):

$$J = \sum U_{xy}$$

Where:

J = J statistic

U_{xy} = the number of observations in group Y which are greater than all observations in group X

Then the standardized test statistic Z is computed:

$$Z = \frac{J - E(J)}{\sqrt{Var(J)}}$$

Where:

$$E(J) = \frac{N^2 - \sum_{i=1}^{k} n_i^2}{4}$$

And

$$Var(J) = N^2(2N + 3) - \sum_{i=1}^{k} n_i^2(2n_i + 3)$$

Where,

n_i = number of observations in group i

N = number of observations for all groups

k = number of groups in total sample

The method for the Jonckheere-Terpstra test is approximately the same as for the Kruskal-Wallis H test. The observations should be ranked, from which U_{xy} can be calculated. Then, after calculating E(J) and Var(J) test statistic Z can be calculated. When Z is higher than the chi-square critical value, the null-hypothesis can be rejected, and the distributions of the sample differ in a certain order (ascending or descending) according to rank. When Z is lower than the critical value, the samples are not significantly different (Ali, et al., 2015).

3.2.3. Logistic regression

In order to determine how a certain variable influences the chance that a binary variable is 0 or 1, a logistic regression can be used. In this research, it will be used to determine the relationship between age and the choice for the low-cost flight alternative. This is in line with earlier studies. For example, Ivanova & Rolfe (2011) tested how opinions about mining developments in mining cities were based on different socioeconomic factors, using a stated preference method to choose between different alternatives. This is also done in this research. According to hypothesis 6, it is expected that the chance of the stated preference alternative for the low-cost flight should be lower when age of the respondent is higher.

A logistic regression is expressed as follows (Hosmer & Lemeshow, 2013):

$$\log(odds) = c + \beta_1 x_1 + \cdots + \beta_k x_k$$

Where:

c = constant

β_i (i = 1, 2, …, k) = coefficient

x_i (i = 1, 2, …, k) = independent variable

log(odds) = log of odds ratio

In this research, the odds ratio can be expressed as follows:

$$Odds\ Ratio = \frac{\pi}{1 - \pi}$$

Where in this research:

π = chance of low-cost alternative being 1.

Hence, the odds ratio is the chance that the binary variable is 1, divided by the chance that the variable is 0. The interpretation of the coefficient β_1 can be found by multiplying the odds ratio by $e^{\beta 1}$. When $e^{\beta 1}$ is lower than 1, the odds ratio decreases. Hence, the chance that the binary variable is equal to 0 increases. When $e^{\beta 1}$ is higher than 1, the odds ratio increases. In this case, the chance the chance that the binary variable is equal to 1 increases.

So in this case, the logistic regression is:

$$\log(odds) = c + \beta_1 * age + \varepsilon$$

And the effect of age on the odds ratio of 'stated preference air' can be found by $e^{\beta 1}$ and increases when $e^{\beta 1}$ is higher than one and decreases when $e^{\beta 1}$ is smaller than one.

3.2.4. OLS regression

In order to determine drivers of the willingness to pay, a regression is performed. To assess whether certain variables have influence on willingness to pay, the correlation matrices of the Berlin and London databases are used. These matrices can be found in Appendix 2.

In the correlation matrices and based on the fact that these characteristics may influence utility someone experiences from a trip, it can be found that the variables importance price, importance travel time, and importance environment are correlated to willingness to pay and are therefore included in the regression as independent variables. Age and travel time are added, because these variables are examined in hypotheses 1 and 5. In order to determine the relationship between those independent variables and the dependent variable WTP, the latter is transformed into logarithms. This is done with travel time as well. Hence, the following regression is performed:

$$Log\ WTP = c + \beta_1 * Log\ Travel\ time + \beta_2 * Importance\ environment + \beta_3 * Importance\ Price + \beta_4 * Age + \beta_5 * Importance\ travel\ time + \varepsilon.$$

By doing this, the regression can be interpreted as follows:

When travel time increases with 1%, WTP increases with β_1% and vice versa. When importance environment increases with 1, WTP increases with β_2*100%. Importance price, age and importance travel time are interpreted similarly.

Also, drivers between variables influencing WTP are examined. Hence, a regression with Importance Environment and importance Price is performed. According to the correlation matrices, no relevant variable is correlated to importance travel time. Thus, this variable is not analysed in depth.

For importance environment, age and gender are relevant variables to analyse according to the correlation matrix. Due to sociocultural factors, it might indeed occur that attitudes differ between those groups and ages (McDonald & Crandall, 2015). Hence, the following regression is performed:

$$Importance\ environment = c + \beta_1 * gender + \beta_2 * age + \varepsilon.$$

Here, importance environment increases with β_1 when gender is 1 (man) compared to 0 (woman). Besides, importance environment increases with β_2 when age increases with 1.

Furthermore, a positive attitude of the contribution of train to environment can be examined. According to the correlation matrix, importance environment is correlated to positive attitude. This is confirmed by He, Mol, Zhang, & Lu (2015), who found that people who value environment as important, usually think travelling by train instead of plane contributes positively to the environment. Hence, the following regression is performed:

$$Positive\ attitude\ contribution\ train\ to\ environment = c + \beta_1 * importance\ environment + \varepsilon.$$

Here, positive attitude increases with β_1 when importance environment increases with 1.

Lastly, it can be expected that importance price differs for different occupation and ages (McDonald & Crandall, 2015). For example, when someone is employed full time, one has a better financial position. Hence, price matters less when choosing between alternatives. These two variables are also correlated with importance price according to the correlation matrix.

$$Importance\ price = c + \beta_1 * employedFT + \beta_2 * age + \varepsilon.$$

Here, importance price increases with β_1 when employedFT is 1 (full time employed) compared to 0 (not full time employed). Age can be interpreted the same as in the equations above.

3.3 Descriptive statistics

Before the results will be listed, it is important to know more about the respondents. The average age of the 124 respondents in this research is 26.4 years old. The exact age distribution can be seen in figure 2, where a strong peak at the age of mid-twenties is visible indeed. 58% of the respondents are male, 41% is female and 1% prefers not to say. The young age of the sample can be seen in occupations of the sample as well. 64% of the sample still classifies as student, 27% is employed full time, 6% is part-time employed and 3% is unemployed (so also not student). All these descriptive statistics can be seen in table 1 as well.

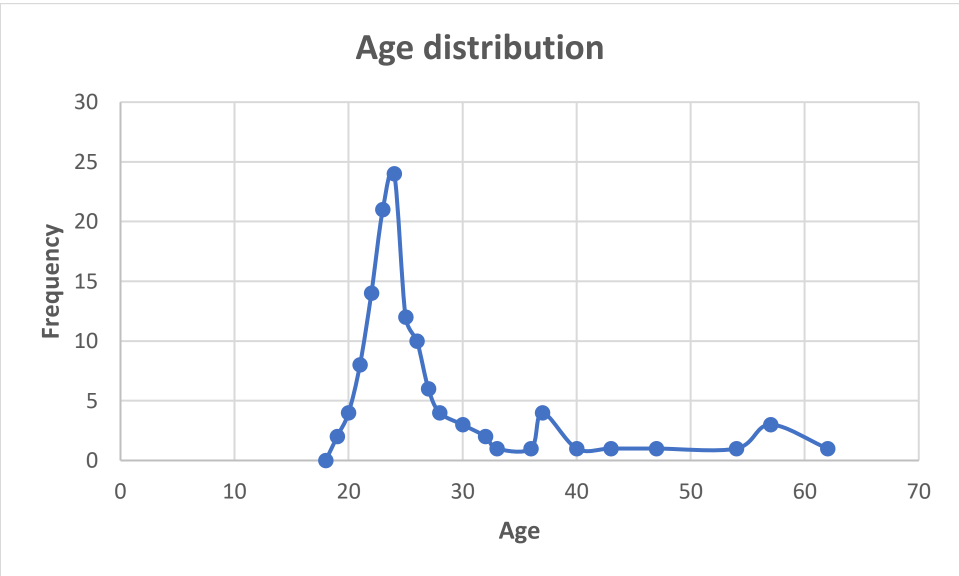
Table 1

Descriptive statistics

Average age	26.4 years			
Gender	58% male	41% female	1% prefers not to say	
Occupation	64% student	27% employed full-time	6% employed part-time	3% unemployed
Travel purpose	90% tourism	10% business		

Figure 2

Age distribution of the total sample



4. Results

In this section, the results based of the survey will be analysed using the methods stated above. This will be done in order of the hypotheses listed in section 2.

Hypothesis 1: willingness to pay for an alternative is higher for alternatives with lower travel time, irrespective of the travel mode.

As said in section two, it is expected that willingness to pay for the alternatives with lower travel time will be higher, corresponding to the findings of Qin, Chen, Cu, & Wang (2014). In order to analyze this, the ordinary least squares regression (OLS) is used with transforming willingness to pay and travel time to logarithms for a better interpretation. By doing this, the interpretation of the coefficient β is as follows: when changing traveltime with 1%, WTP will change with β%. As seen in chapter 3, it might be expected based on correlations between the variables that travel time, importance environment, importance travel time, importance price and age have a relationship with willingness to pay and are therefore included in the regression. The results of the regression for London and Berlin can be seen in table 2. In figure 3 it can be seen that a majority of people values travel time as an important or very important determinant in order to choose for a certain modality.

Figure 3

Distribution respondents importance travel time on Likert scale.

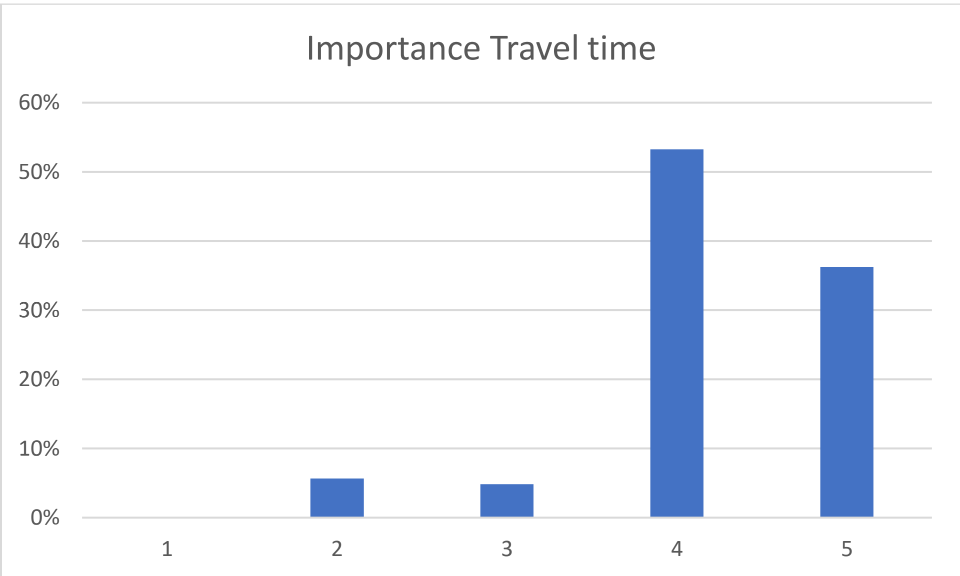


Table 2

Regression results WTP

	London			Berlin		
Log WTP	**Coefficient**	**Std. Error**	**P-value**	**Coefficient**	**Std. Error**	**P-value**
Log Travel time	-0.995	0.081	0.000	0.436	0.118	0.000
Importance env.	0.043	0.025	0.091	0.051	0.026	0.050
Importance price	-0.089	0.041	0.030	-0.087	0.041	0.037
Importance trav.	-0.095	0.036	0.009	-0.137	0.037	0.000
Age	0.020	0.004	0.000	0.019	0.004	0.000
Constant	9.994	0.619	0.000	1.640	0.756	0.030
	F-statistic = 48.85, **R-squared** = 0.336			**F-statistic** = 17.19, **R-squared** = 0.118		

From table 2, it can be seen that for the Amsterdam-London route, willingness to pay decreases with 0.995% when travel time increases with 1%. This can be interpreted as a time elasticity of minus 1. The relationship is also statistically significant given the p-value. When importance environment raises with 1, willingness to pay rises with 4.3% for London and 5.1% for Berlin. When importance price increases with 1, willingness to pay decreases with 8.9% for London and 8.7% for Berlin. When importance travel time increases with 1, willingness to pay decreases with 9.5% for London and 13.7% for Berlin and when age increases with 1 year, WTP increases with 2% for London and 1.9% for Berlin. All variables are statistically significant.

The F-statistic for London and the R-squared mean that a huge part of the variation in log willingness to pay is explained by the variables. The F-statistic for Berlin is lower, but still indicates that a model incorporating log travel time is significant, but the low R-squared means that not a lot of the variation of the model with log travel time explains variation in log WTP. Hence, the positive effect of log travel time on WTP in the Berlin case is less significant than the negative effect which can be seen in the London model. This can be explained by the fact that for a trip to London, the alternatives in the survey are already in place, where for Berlin this is not the case, which makes a valuation of the trip more difficult for the respondent.

Based on the significantly higher F-statistic and R-squared for London than for Berlin, hypothesis one is not rejected.

Hypothesis 2: willingness to pay for train is higher for people who value environmental characteristics as more important.

In order to measure whether there is willingness to contribute to this case (travelling by train instead of plane), willingness to pay for the train alternative is used. It is assumed that willingness to contribute is higher when willingness to pay for train is higher. As stated in chapter 2, it seems logical that people who value environmental characteristics of a trip as more important, are also willing to pay more for a more environmentally beneficial ticket and are hence willing to contribute. This hypothesis tests whether this is indeed the case. Furthermore, it is in this case also essential that people believe that travelling by train is actually beneficial for the environment. Therefore, not only the effect of a higher valuation of environmental impacts importance (based on Likert scale) is considered in this analysis, but also a more positive attitude towards a positive contribution of train to environment will be analysed. This analysis can be seen in table 3 and figure 5. As can be seen in figure 4, the distribution for importance of environmental factors is more even. Thirty percent values environment as not important at all or not important. Thirty percent is neutral and nearly forty percent values environment as at least important. For the exact questions, see appendix 1.

First a Kruskal-Wallis test will be performed to test whether there exist differences between population groups. The population groups are in this case based on the importance or positive attitude respondents gave to environmental impacts or positive impacts of travelling by train with 1 being the least important/positive and 5 being the most important/positive. The different group sizes can be seen in table 3.

As stated in paragraph 3.2.4., importance environment and positive attitude towards train are influenced by other variables. It can be seen in table 4 that importance of environment rises with 0.025 when age rises with 1, and that being a man decreases importance of environment on average with 0.585. Both variables are statistically significant and explain variations in importance environment, given the F statistic.

Importance of environment itself influences the positive attitude towards environmental contribution of travelling by train, as can be seen in table 5. When importance of environment increases, the positive attitude increases with 0.202. Hence, people who value environmental characteristics as more important, also believe more in environmental benefits of travelling by train. This relationship is statistically significant. Hence, when someone is older and female, it is likely that the individual values environment as more important and likewise has indirectly a more positive attitude towards environmental contribution of train to environment.

When a difference between the distributions of the groups has to be assessed, a Jonckheere-Terpstra test will be applied. This test will be focused on ascending order, since according to the hypothesis it is expected that WTP is higher when the group number is higher. The p-values of the tests for London can be seen in table 6. For Berlin, three different train options exist: the current ICE, the ICE with 45 minutes time-savings as mentioned in chapter 1, and the ICE with two hours' time savings. therefore, three different p-values for each test in Berlin do exist. The results for Berlin can be seen in table 7.

Table 3

Group sizes Likert questions environmental impacts and attitude towards environmental benefits of travelling by train instead of plane

Groups	Environmental Impacts	Positive att. Towards env. Benefits train
1	14	2
2	25	3
3	35	5
4	39	52
5	11	62

Table 4

Regression results importance environment

Importance env.	Coefficient	Std. Error	P-value
Age	0.025	0.005	0.000
Gender	-0.585	0.106	0.000
Constant	2.742	0.167	0.000
	F-statistic = 29.92, **R-squared** = 0.091		

Table 5

Regression results positive attitude environmental benefits of travelling by train

Pos. train to env.	Coefficient	Std. Error	P-value
Importance env.	0.202	0.035	0.000
Constant	3.743	0.125	0.000
	F-statistic = 33.45, **R-squared** = 0.083		

Figure 4

Distribution Likert scale importance environment

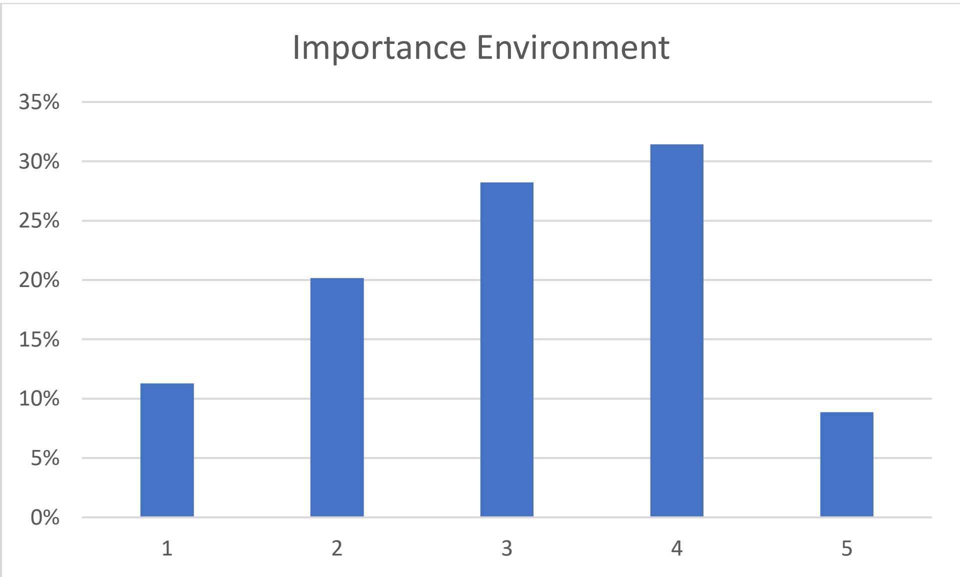


Table 6

Kruskal-Wallis and Jonckheere-Terpstra test (ascending order) p-values for London

P-values tests	**London**	
	Environmental Impacts	**Positive att. Towards env. Benefits train**
Kruskal-Wallis	0.017	0.008
Jonckheere-Terpstra (ascending order)	0.008	0.018

Table 7

Kruskal-Wallis and Jonckheere-Terpstra test (ascending order) p-values for Berlin

P-values tests	Berlin current		Berlin 45 min time saving		Berlin 2 hours' time saving	
	Environm. Impacts	Positive att. train	Environm. Impacts	Positive att. train	Environm. Impacts	Positive att. train
Kruskal-Wallis	0.000	0.001	0.000	0.000	0.000	0.000
Jonckheere-Terpstra (ascending order)	0.000	0.000	0.000	0.000	0.000	0.000

In both table 6 and 7, it can be seen that for both London and all the Berlin train alternatives the Kruskal-Wallis test p-values are lower than the critical value of 0.05, which means that in all the cases the null-hypothesis of the Kruskal-Wallis test (all distributions in groups within the sample are the same) can be rejected. Hence, a difference in willingness to pay exists between the different attitudes towards importance of environmental impacts and the benefits of travelling by train instead of airplane.

Likewise, the p-value of the Jonckheere-Terpstra test (in ascending order) is lower than the critical value of 0.05. Therefore, it can be concluded that willingness to pay for train is higher for groups who value environmental impacts of their trip as more important and for groups who think train instead of plane is beneficial for the environment. In the latter, it should however be noted that nearly the entire sample agrees or strongly agrees with the statement that they believe that travelling by train instead of plane is beneficial for the environment. Therefore, the sample is skewed and no proper conclusions on that variable can be drawn.

However, given all the results, hypothesis two is not rejected.

Hypothesis 3: willingness to pay for air transport is lower for people who value environmental characteristics as more important.

Following the same intuition as in hypothesis two, people are also willing to contribute when willing to pay less for air transport, because of the worse environmental impacts of travelling by plane. Again, first the Kruskal-Wallis test will be performed, and then the Jonckheere-Terpstra test, this time testing for descending order, since it is expected that willingness to pay will decrease when the importance of environmental impacts is valued higher.

For London, a primary connection (between Schiphol and Heathrow) and a low-cost connection (between Eindhoven and Stansted) do exist. The p-values can be seen in table 8. For Berlin, only one flight option exists. This option can be seen in table 9.

Table 8

Kruskal-Wallis and Jonckheere-Terpstra test (descending order) p-values for London

P-values tests	**London Primary** **Environm. Impacts**	**London LCC** **Environm. Impacts**
Kruskal-Wallis	0.134	0.257
Jonckheere-Terpstra (descending order)	0.932	0.895

Table 9

Kruskal-Wallis and Jonckheere-Terpstra test (descending order) p-values for Berlin

P-values tests	**Berlin** **Environmental Impacts**
Kruskal-Wallis	0.008
Jonckheere-Terpstra (descending order)	0.934

The Kruskal-Wallis test for both London Primary and low cost points out that there is no significant evidence that there is a difference in willingness to pay distributions between the various groups, since the P-value is higher than the critical value of 0.05. This can be seen as well in the outcome of the Jonckheere-Terpstra test, where the p-values also exceed the critical chi square value.

For Berlin, the Kruskal-Wallis test points out that there exists a significant difference in willingness to pay distributions between the various groups, since the P-value is smaller than 0.05. However, this difference is not in the order as is expressed in the hypothesis, since the Jonckheere-Terpstra test for descending order is not significant.

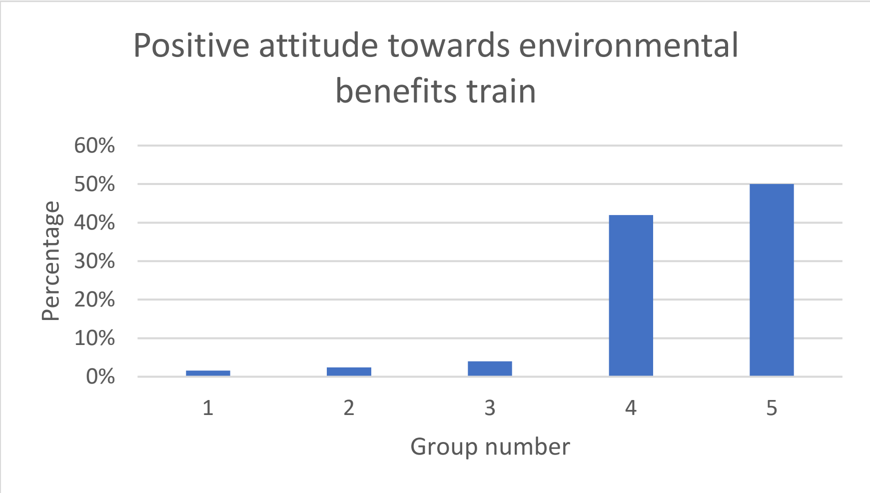
Based on these findings, it can be concluded that respondents that value environmental impacts as more important in their travel mode decision, do not necessarily pay less for airplane tickets. Therefore, hypothesis 3 is rejected.

Hypothesis 4: a majority of people thinks that travelling by high-speed rail instead of travelling by plane is environmentally beneficial.

The fourth hypothesis focuses more on the awareness part of this case: when many people believe that travelling by train instead of airplane to destinations contributes positively to the environment, people are more likely to travel by train. Therefore, the results of the survey question about attitude towards a positive contribution of train instead of airplane are analysed. The results can be seen in table 3 under the results of hypothesis one and in figure 5.

Figure 5

Distribution of positive attitude towards environmental benefits of train to environment



In figure 5, it can be seen that approximately 40% of the sample agrees with the statement that a substitution of train instead of airplane contributes positively to the environment and even 50% agrees strongly with the statement. Based on these results, it can be concluded that there exists awareness in this matter and people think high speed rail is environmentally beneficial. As can be seen under hypothesis 2, this is influenced by people who value environmental characteristics of travelling as important, which on its part is influenced by age and gender.

As a result of these findings, hypothesis 4 is not rejected.

Hypothesis 5: willingness to pay is positively correlated with age and the stated preference points less towards the low cost alternative when age is higher.

Due to the fact that people of higher age often are better paid, it can be expected that willingness to pay rises when age rises. In order to see the relation between the two variables, a regression of age on log wtp is performed. WTP is transformed into logarithms for the sake of understanding. As seen in chapter 3, it might be expected based on correlations between the variables that travel time, importance environment, student and travel time have a relationship with willingness to pay and are therefore included in the regression. The results can be seen in table 10, which is a copy of table 2.

Table 10

Regression results WTP

Log WTP	London			Berlin		
	Coefficient	**Std. Error**	**P-value**	**Coefficient**	**Std. Error**	**P-value**
Log Travel time	-0.995	0.081	0.000	0.436	0.118	0.000
Importance env.	0.043	0.025	0.091	0.051	0.026	0.050
Importance price	-0.089	0.041	0.030	-0.087	0.041	0.037
Importance trav.	-0.095	0.036	0.009	-0.137	0.037	0.000
Age	0.020	0.004	0.000	0.019	0.004	0.000
Constant	9.994	0.619	0.000	1.640	0.756	0.030
	F-statistic = 48.85, **R-squared** = 0.336			**F-statistic** = 17.19, **R-squared** = 0.118		

The F-statistic for both regressions for Berlin and London indicates that the variables explain variation in log WTP. The R-squared can be higher for Berlin, since the total regression explains not that much of the variation in Log WTP. The coefficient can be interpreted as follows: when age rises with 1, willingness to pay rises with 0.020*100% = 2.0% for London and with 1.9% for Berlin. From this, it can be concluded that age and WTP are positively correlated. The total interpretation can be found under hypothesis 1.

Multiple variables can influence the willingness to pay. One of them is importance of price. As is stated in chapter 3, according to the correlation matrix, both age and full time employment can be drivers of the importance of price in making modality choice. The results in table 11 confirm this. When someone becomes one year older, the importance of price decreases with 0.037. Hence, older people take price less into account when making their modality choice. It can also be seen that importance of price decreases with 0.204 when people are employed full time compared to the mean participant, which contains mainly students. Both variables are statistically significant.

Table 11

Regression results importance price

Importance price	Coefficient	Std. Error	P-value
Age	-0.037	0.004	0.000
Employed FT	-0.204	0.080	0.023
Constant	2.742	0.149	0.000
	F-statistic = 57.50, **R-squared** = 0.174		

Next, it can be analysed whether the stated preference indicates the same: namely that people of higher age tend to choose less for the cheap air option. In order to do this, a logit regression will be performed. The results can be seen in tables 12 and 13.

Table 12

Logit regression results stated preference air secondary and age London

	London		
SP Air secondary	**Coefficient**	**Std. Error**	**P-value**
Age	-0.070	0.019	0.000
Constant	1.229	0.476	0.010
	Prob Chi-Squared = 0.000		

Table 13

Logit regression results stated preference air and age Berlin

	ICE Current			**ICE time savings**		
SP Air	**Coefficient**	**Std. Error**	**P-value**	**Coefficient**	**Std. Error**	**P-value**
Age	-0.041	0.011	0.000	-0.051	0.012	0.000
Constant	1.173	0.299	0.000	1.479	0.324	0.000
	Prob Chi-Squared = 0.000			**Prob Chi-Squared** = 0.000		

All the chi-squared probability values are 0.000, which means that all the logit regressions are statistically significant. The interpretation of the coefficient is as follows: a one year rise in age means a multiplication of the odds ratio with: $e^{coefficient\ age}$, which is explained in paragraph 3.2.3.

The outcomes of this formula for each logit regression are listed in table 14.

Table 14

Odds ratio changes for standard preference air.

	Odds ratio For SP Air
London	0.932
Berlin ICE Current	0.960
Berlin ICE Time Savings	0.950

Hence, this means that for all the logit regressions, the odd ratio decreases when age rises with 1. This implicates that the chances of people preferring the flight decreases for London and for Berlin in both the current situation and the situation with faster high-speed rail when they get older. Based on these findings and on the regression with willingness to pay and importance of price, hypothesis five is not rejected.

Hypothesis 6: demand for low-cost air travel remains approximately constant after high-speed rail introduction, because passengers generally prefer the alternative with the lowest price.

One of the most important factors in order to choose for transport modality is price. Therefore, it can be expected that passengers tend to choose for the cheapest travel option. Normally, train is more expensive than air travel (at least more expensive than low-cost air travel). In order to test whether passengers prefer the cheapest option, first the importance of price for passengers in making modality choice has to be identified. In figure 6 it can be seen that nearly 90% values price as important or very important in order to make a modality choice. What thrives importance of price can be seen in table 11.

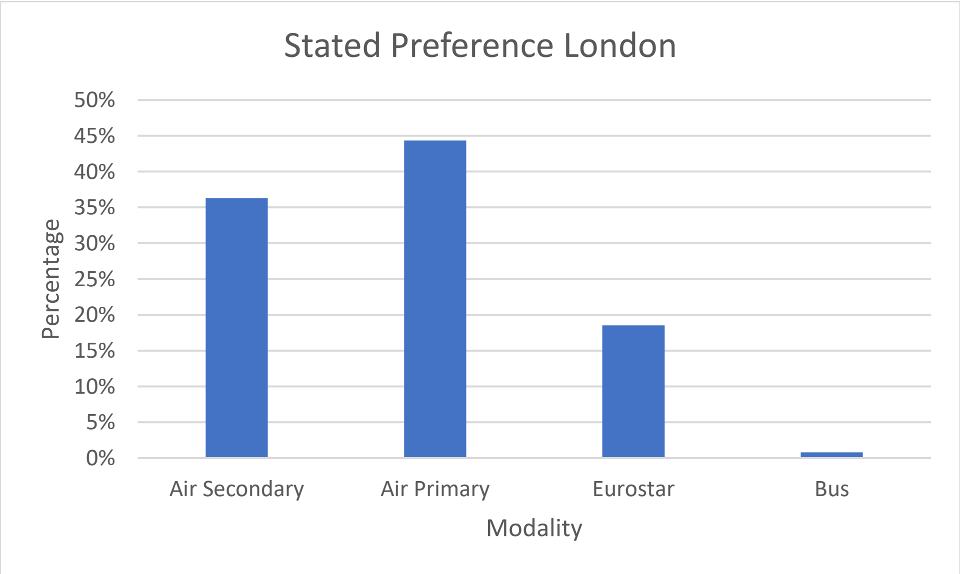
Figure 6

Distribution importance price Likert question

In order to test whether demand for low-cost air travel remains approximately the same, stated preference of customer for different modalities can be reviewed. First, the most preferred outcome for London is revised. The distribution can be seen in figure 7.

Figure 7

Distribution stated preference London



The bus is in this case the cheapest option. Only 1% of the respondents choose for this modality, probably caused by the long travel time. Distribution among the alternatives with approximately the same travel time is probably more representative in order to assess the impact of price on the modality choice. As can be seen in the stated preference questions in appendix 1, price difference between secondary and primary air travel is small in terms of absolute price. In figure 7, it can be seen that nearly 80% prefers air travel options instead of the Eurostar, with the latter being two times as expensive as the flight options. From this, it can be concluded that price plays an important role in modality choice. However, this can change when travel time changes for the different travel options. Therefore, two different situations in Berlin are analysed: one with the current ICE travel time of 6 hours and twenty minutes and one after two-hour time savings, visible in figures 8 and 9.

Figure 8

Distribution revealed preference Berlin

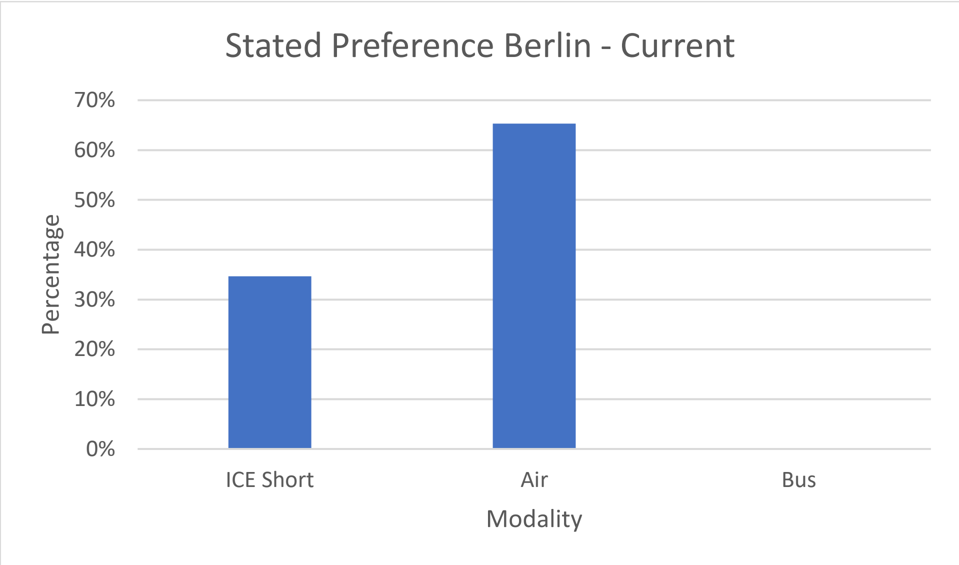
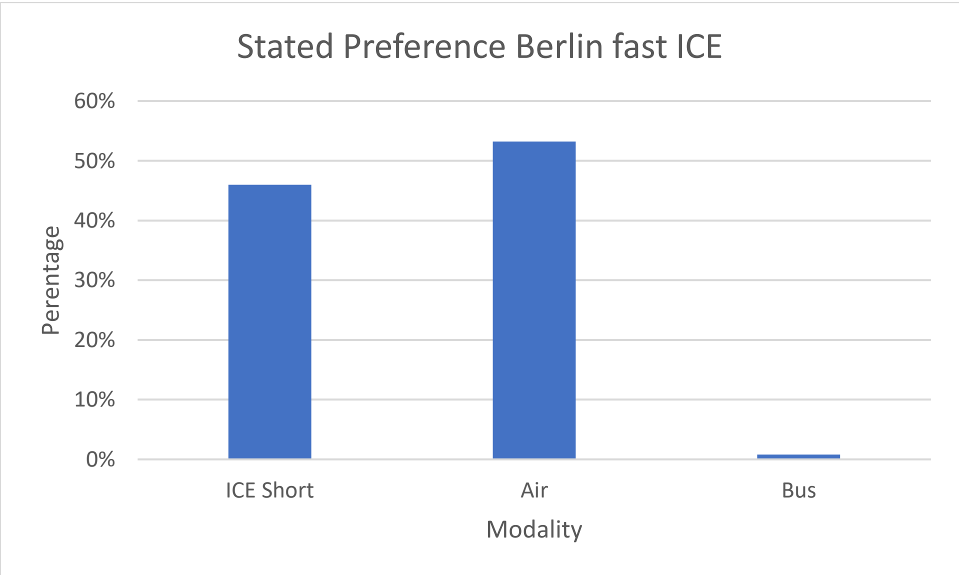


Figure 9

Distribution revealed preference Berlin after time improvement.



Again, the bus alternative with long travel time is not preferred by any respondent. In both situations, both before and after time savings with ICE, the air option is the most preferred option. However, it can be seen that the ICE is preferred by a bigger part of the sample after the time savings of two hour, despite a price increase of 10 euros. Hence, not only price but also travel time seems to be important in travel mode choice. Based on these results, it can be concluded that not always the cheapest option is preferred and therefore, demand for low cost air travel does not remain constant after ICE introduction (or improvement). Hence, hypothesis 6 is rejected.

Hypothesis 1: *willingness to pay for an alternative is higher for alternatives with lower travel time, irrespective of the travel mode. – not rejected*

Hypothesis 2: *willingness to pay for train is higher for people who value environmental characteristics as more important. – not rejected*

Hypothesis 3: *willingness to pay for air transport is lower for people who value environmental characteristics as more important. - rejected*

Hypothesis 4: *a majority of people thinks that travelling by high-speed rail instead of travelling by plane is environmentally beneficial. – not rejected*

Hypothesis 5: *willingness to pay is positively correlated with age and the stated preference points less towards the low cost alternative when age is higher. – not rejected*

Hypothesis 6: *demand for low-cost air travel remains approximately constant after high-speed rail introduction, because passengers generally prefer the alternative with the lowest price. – rejected*

5. Conclusions and discussion

In this report, a review is made of the important travel determinants in order to choose for a modality on the routes Amsterdam – London and Amsterdam – Berlin. This is done to determine policy advice using the behavioural change matrix. In order to assess which policy is appropriate, awareness and willingness to contribute have to be determined in the case of substituting air travel with high speed rail. Other variables which can contribute to modality choice are determined as well. This is done using a survey. The data resulting from the survey is analysed with the Kruskal-Wallis test, the Jonckheere-Terpstra Test and a logistic regression. Drivers for the regressed variables are analysed more in depth with OLS, in order to determine whether policy has to differ for different socioeconomic groups.

Awareness

As stated in chapter two, awareness is a key concept in the behavioural change matrix and can be defined as the knowledge of an individual about how their behaviour influences other people's lives. This awareness is in this research determined by the variables 'importance environment' and 'positive attitude benefits train to environment', which are ranked based on Likert Scale questions. Hypothesis two pointed out that the answers of 'importance environment' are almost evenly distributed from very low importance to very high importance. This can be interpreted as a slight lack of awareness of environmental damage travelling can cause.

In order to determine the perception of the environmental benefits that can be achieved by travelling by high speed rail instead of plane, the attitude towards high speed rail is assessed by Likert scale questions. It is found in hypothesis that the majority of the respondents has a positive or even very positive attitude towards high speed rail. Hence, awareness of possible benefits of high speed rail is high.

Willingness to contribute

Willingness to contribute is the second key concept in the behavioural change matrix. Willingness to contribute can be defined as the motivation of an individual to act upon their awareness and achieve a certain goal. Willingness to contribute is in this research determined by willingness to pay and stated preference. According to hypothesis 2, willingness to pay for high speed rail is higher for people who value environmental aspects of travelling as more important. This can be interpreted as a high willingness to contribute. However, hypothesis 3 contradicts this. This hypothesis pointed out that willingness to pay for airplane tickets, which are perceived to be worse for the environment, does not decrease when 'importance environment' is valued higher. This can be interpreted as low willingness to contribute.

In hypothesis 6, it can be seen that for stated preference, the majority of the respondents chooses for air alternatives. This also can be interpreted as low willingness to contribute.

Other travel characteristics influencing modality choice

Hypotheses 1 and 6 are used in order to determine other important factors that contribute to modality choice. Hypothesis 1 pointed out that the majority of the respondents in this research see travel time as an important or very important characteristic in modality choice. Besides, it is found that willingness to pay for modality is higher when travel time is shorter. In hypothesis 6 it is found that after high speed rail improvements on the corridor Amsterdam-Berlin, which results in significant time savings, also leads to an increase of demand for high speed rail based on the stated preference questions. Hence, travel time is an important characteristic for people to choose modality. In hypothesis 6, it is also found that the most preferred option is not always the alternative with the lowest price. When travel time decreases substantially, people are willing to pay more for an alternative. However, in hypothesis 6 it is also found that the majority of people thinks price is an important or very important characteristic in order to choose between modalities according to the Likert Scale questions. The earlier mentioned stated preference analysis however points out that travel time is (slightly) more dominant than price for modality choice.

Socioeconomic factors influencing modality choice

This study also made clear that different groups have a statistically different valuation of certain travel mode characteristics. In hypothesis 1, it is made clear that willingness to pay increases when age rises. Thus, people generally are willing to pay more for trips when becoming older. Besides, in hypothesis two, it is also found that people also value environmental factors as more important when they become older. Also, women tend to value environmental impacts of their trips as a more important characteristic when choosing modality. In hypothesis 5 it is found that importance of price decreases when age is higher. This is in line with the findings for willingness to pay and the fact that in hypothesis 5 it is found that stated preference points less towards the low cost alternatives. Lastly, importance of price is also lower for people who are full time employed. Hence, it can be concluded that age is an important socioeconomic variable and that policy has to be adjusted for different ages. This is also the fact in lesser extent for gender.

Policy advice

Using the assessment of awareness, willingness to contribute and by the behavioural change matrix, policy advice can be given. It is concluded that awareness for high speed rail as an environmentally friendly alternative for air travel is high, however importance of environment is low. Therefore, it can be expected that people will generally not choose for the environmentally friendly option based. This is in line with the relatively low willingness to contribute.

According to the behavioural change matrix, the right policy includes both educational measures and incentives to change behaviour. The first can be achieved by campaigns that promote environmentally friendly behaviour and addresses the importance of environmental factors in modality choice and the harm transport can cause. By doing this, social norms can change. However, effects may only become visible on the longer term. It can be wise to aim these campaigns on younger people, since according to this study, younger people have a lower valuation of importance of environmental factors. Also, the campaign should be aimed more at males, since women generally are more aware of environmentally factors of travelling.

Also incentives can be used in order to change behaviour of people. This can be with positive or negative incentives: subsidies or taxes. Suggestions are to take different socioeconomic factors into account for policy. Based on the fact that in this study younger people tend to have a lower willingness to pay and lower environmental awareness, student discounts can be a useful measure in order to nudge this group towards travelling by high speed rail. More general measures are higher taxes on airplane tickets, next to the already imposed short haul airplane taxes. When these tickets are more expensive, people are less likely to buy them, which is supported by the fact that people value price as an important factor for modality choice. This effect can also be achieved by decreasing price of high speed rail. Another important factor is travel time. It is found in this study that lower travel time means that the option is more favourable. Therefore, the announced time savings on the Amsterdam-Berlin corridor might result in the desired effect of people choosing more for the high speed rail alternative.

Implications for stakeholders

Next to the role of the government, the findings and policy advices lead to different implications for the different stakeholders. Airports have to substantially change their way of operations. Primary (international) airports have to be connected to high speed rail networks in order to offer all the alternatives and hence, to be an attractive node to travel. The high speed rail introduction will lead to a possible reduction of the amount of flight movements at the airport, which can be taken over by international flights. The high speed rail alternatives then provide short haul travel. Due to this fact, the environmental benefits of high speed rail introduction are questionable, since flights will only be replaced and possibly will not decrease.

The implications for secondary (regional) airports are different. An important share of the flight movements at these airports are short haul flights. Besides, these airports are less likely to be connected to high speed rail networks. Hence, these airports will likely be less profitable.

Airports can also be partially operated by the government. By doing this, the government can directly influence operations of the airport and can therefore steer operations in order to achieve policy goals faster.

The introduction and expansion of high speed rail also influences passengers. Passengers have more alternatives to choose and are therefore more likely to maximise their utility. This increase in alternatives will possibly lead to the so-called traffic generation effect, where people tend to travel more when more alternatives are available. This leads to doubts about environmental effectiveness of the expanded high speed rail network as well. Other implications for passengers originate from the policy advice above.

For railway operators demand for service may rise due to the decrease of travel time. However, more parties are likely to enter the market, therefore all current transport providers have to stay competitive and evaluate their performance all the time. In order to create a pan-European network, different national railway maintenance companies have to cooperate, supported by the government. This is necessary in order to make the network work.

For airlines high speed rail introduction may have various impacts. Full service carriers are likely to change to more intercontinental services. For low-cost carriers, this is more difficult, since these operate continental most of the time. Only for ultra-low-cost airlines like Ryan Air, the consequences might be limited, since they offer tickets at a very low price and demand decreases might be limited. However, both LCC's and ULCC's should revise their cost structure in order to offer tickets at an even lower price, or should come up with another solution in order to keep a competitive advantage compared to high-speed rail. For example, these companies could focus more on *medium-haul* destinations (for example with three hours flight time) which are not easy to reach with high-speed rail, or should change their frequency. When possible, cooperation between airlines and railway operators may be beneficial for both parties. This leads to an improved service level for passengers.

Limitations and possible further research

Downsides of this research is the relatively young and small group of respondents. This means that the sample might not be representative for the entire population. Younger people tend to have a lower budget, therefore their willingness to pay for more environmentally beneficial alternatives might be lower and they tend to choose more for the cheaper stated preference option. Also, the questions might be difficult to answer for the respondents, because estimating normal prices for flight tickets is hard. Hence, the alternatives might be valued wrong by the respondents.

Suggestions for further research could be a HSR and air market comparison for other markets than Amsterdam-Berlin and Amsterdam-London. This might lead to different conclusions. Also, revealed preference could be researched after the opening of the faster high speed rail connection to Berlin. Willingness to contribute can be measured best when reviewing revealed preference. Also, it might be interesting to incorporate other determinants for travel mode choice like comfort to see how those variables are related to environmentally considerations. Other socioeconomic drivers that could have been included were salary and educational attainment. These questions could be included in surveys for further research.

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Appendix 1

Dear participant,

My name is Richard Fokker and I am currently writing my master thesis to complete my MSc in Urban, Port and Transport Economics at the Erasmus School of Economics. The survey that follows will provide some useful insights for the research of my thesis. The aim of this survey is to find people's preferences regarding ways of transport to various European cities.

This questionnaire consists of three different parts. In the first part, you will be asked to give your valuation for trips with different transport modes to London. In the second part, the destination will be Berlin. Both trips will originate from Amsterdam. The definition of transport mode, a term which you will see multiple times in this survey, is: the way of transportation, for example plane, train, bus, car, etcetera.

The last part will consist a couple of questions regarding some characteristics which are important in choosing a transport mode.

Your answers will remain anonymously and only be used in the context of this specific scientific research. Participation in this survey is voluntary and should take you maximum 5 minutes.

By starting the survey below, you agree to voluntary participate in this research.

Thank you for your time!

1. Age in years:
2. Gender
    - Male
    - Female
    - Other
    - Prefer not to say
3. What is your current employment status?
    - Student
    - Employed part-time
    - Employed full-time
    - Unemployed
    - Retired
    - Other, namely:

The following questions will focus on a journey to be made from locations in the Netherlands to London St. Pancras International Railway Station. For each journey, transport mode (plane, train or bus), travel time and eventual transfers from one mode to another are listed in a table. The total journey time is listed at the bottom of the table in each question. <u>Assume you can freely choose your departure time</u>. You will be asked to value each different journey for a **one way trip**.

4. Assume you want to travel from the centre of Amsterdam (Amsterdam Central Station) to the centre of London (St. Pancras International) by using the Eurostar train (see details in the table below). No further transfer is needed. What would you be willing to pay for a **one way Eurostar train** ticket?

Departure station	Amsterdam Central Station
Arrival station	London St. Pancras
Check in process	1 hr 15 mins
Train journey duration	3 hrs 55 mins
Total check-in + journey time	5 hrs 10 mins

5. Assume that you make a trip to London by plane, departing from Amsterdam Schiphol with final destination the city centre of London (St. Pancras International). You fly from Schiphol to Heathrow. From there on, you need to change to the local public transport to get to London St. Pancras International. You can ignore the local public transport costs. What would you be willing to pay for a **one way flight** ticket?

Departure Airport	Amsterdam Schiphol Airport
Arrival Airport	London Heathrow
Check in process at Schiphol	2 hrs
Flight duration	1 hr 20 mins
Transfer time plane → London Metro	30 mins
Travel time London Heathrow → St Pancras International	1 hr
Total check-in + journey time	4hrs 50 mins

6. Assume that you make a trip to London by plane, departing from Eindhoven Airport with final destination the city centre of London (St. Pancras International). You fly from Eindhoven Airport to London Stansted. From there on, you need to change to the local public transport to get to London St. Pancras International. You can ignore the local public transport costs. What would you be willing to pay for a **one way flight** ticket?

Departure Airport	Eindhoven Airport
Arrival Airport	London Stansted
Check in process at Eindhoven	2 hrs
Flight duration	1 hr 10 mins
Transfer time plane → train	30 mins
Travel time London Stansted → St Pancras International	1 hr 5 mins
Total check-in + journey time	4 hrs 45 mins

7. Assume that you make a trip to London by Flixbus, departing from Amsterdam Sloterdijk with final destination the city centre of London (St. Pancras International). You arrive at Buckingham Palace Road. From there on, you need to change to the local public transport to get to London St. Pancras International. You can ignore the local public transport costs. What would you be willing to pay for a **one way Flixbus** ticket?

Departure Station	Amsterdam Sloterdijk
Arrival Station	Buckingham Palace Road
Check in process at Amsterdam Sloterdijk	15 mins
Bus journey duration	11 hrs
Travel time Buckingham Palace Road → St Pancras International	20 mins
Total check-in + journey time	11 hrs 35 mins

8. Still assume you want to travel from Amsterdam to London St. Pancrass international (one way). Which of the following alternatives would you pick to travel with?
    - Eurostar Train Amsterdam Central Station - London St. Pancras, 5 hrs 10 minutes duration including check in for €82
    - Flight Schiphol Airport - London Heathrow, 4 hrs 50 minutes duration including check in and transfer from airport to city for €40
    - Flight Eindhoven Airport - London Stansted, 4 hrs 45 minutes duration including check in and transfer from airport to city for €31
    - Flixbus Amsterdam Sloterdijk - London Buck. Palace Rd., 11 hrs 35 minutes duration including check in and transfer to St. Pancras for €34

The following questions will focus on a journey to be made from locations in the Netherlands to Berlin Hauptbahnhof. For each journey, transport mode (plane, train or bus), travel time and eventual transfers from one mode to another are listed in a table. The total journey time is listed at the bottom of the table in each question. Assume you can freely choose your departure time. You will be asked to value each different journey for a **one way trip**.

9. Assume that you make a trip to Berlin by the ICE (Intercity Express train), departing from Amsterdam Central Station towards the city centre of Berlin (Berlin Hauptbahnhof). No further transfer is needed. What would you be willing to pay for a **one way ICE train** ticket?

Departure Station	Amsterdam Central Station
Arrival Station	Berlin Hauptbahnhof
Check in process at Amsterdam Central Station	15 mins
Train journey duration	6 hrs 20 mins
Total check-in + journey time	6 hrs 35 mins

10. Assume that you make a trip to Berlin by plane, departing from Amsterdam Schiphol towards the city centre of Berlin (Berlin Hauptbahnhof). You arrive at Berlin Schönefeld Airport. From there on, you need to change to the local public transport to get to Berlin Hauptbahnhof. You can ignore the local public transport costs. What would you be willing to pay for a **one way flight** ticket?

Departure Station	Amsterdam Schiphol
Arrival Station	Berlin Schönefeld
Check in process at Schiphol	2 hrs
Flight duration	1 hr 30 mins
Transfer time plane → train	30 mins
Travel time Berlin Schönefeld Airport → Berlin Hauptbahnhof	40 mins
Total check-in + journey time	4 hrs 40 mins

11. Assume that you make a trip to Berlin by Flixbus, departing from Amsterdam Sloterdijk towards the city centre of Berlin (Berlin Hauptbahnhof). You will arrive at Berlin Omnibusbahnhof. From there on, you need to change to the local public transport to get to Berlin Hauptbahnhof. You can ignore the local public transport costs. What would you be willing to pay for a **one way Flixbus** ticket?

Departure Station	Amsterdam Sloterdijk
Arrival Station	Berlin Omnibusbahnhof
Check in process at Amsterdam Sloterdijk	15 mins
Bus journey duration	8 hrs 10 mins
Travel time Berlin Omnibusbahnhof → Berlin Hauptbahnhof	25 mins
Total check-in + journey time	8 hrs 50 mins

12. Assume that you make a trip to Berlin by ICE, departing from Amsterdam Central Station towards the city centre of Berlin (Berlin Hauptbahnhof). No further transfer is needed. What would you be willing to pay for a **one way ICE train** ticket?

Departure Station	Amsterdam Central Station
Arrival Station	Berlin Hauptbahnhof
Check in process at Amsterdam Central Station	15 mins
Train journey duration	5 hrs 35 mins
Total check-in + journey time	5 hrs 50 mins

13. Assume that you make a trip to Berlin by ICE, departing from Amsterdam Central Station towards the city centre of Berlin (Berlin Hauptbahnhof). No further transfer is needed. What would you be willing to pay for a **one way ICE train** ticket?

Departure Station	Amsterdam Central Station
Arrival Station	Berlin Hauptbahnhof
Check in process at Amsterdam Central Station	15 mins
Train journey duration	4 hrs 20 mins
Total check-in + journey time	4 hrs 35 mins

14. Still assume you want to travel from Amsterdam to Berlin Hauptbahnhof (one way). Which of the following alternatives would you pick to travel with?
    - ICE Amsterdam Central Station - Berlin Hauptbahnhof, 6 hrs 35 minutes duration including check in for €38
    - Flixbus Amsterdam Sloterdijk - Berlin Omnubisbahnhof, 8 hrs 50 mins duration including check in and transfer to Berlin Hauptbahnhof for €29
    - Flight Schiphol Airport - Berlin Schönefeld, 4 hrs 40 minutes duration including check in and transfer from airport to city for €30
15. Still assume you want to travel from Amsterdam to Berlin Hauptbahnhof (one way). Which of the following alternatives would you pick to travel with?
    - ICE Amsterdam Central Station - Berlin Hauptbahnhof, 4 hrs 35 minutes duration including check in for €49
    - Flixbus Amsterdam Sloterdijk - Berlin Omnubisbahnhof, 8 hrs 50 mins duration including check in and transfer to Berlin Hauptbahnhof for €29
    - Flight Schiphol Airport - Berlin Schönefeld, 4 hrs 40 minutes duration including check in and transfer from airport to city for €30
    - In the last part, your valuation of the importance of some characteristics which influence your choice will be asked.
16. For what purpose do you travel most?
    - Business
    - Tourism
    - Other, namely:
17. How important is price for you when choosing a type of transport mode (transport mode = type of transport e.g. bus, plane etcetera)?
    - Not at all important
    - Low importance
    - Neutral
    - Important
    - Very important
18. How important is travel time for you when choosing a type of transport mode (transport mode = type of transport e.g. bus, plane etcetera)?
    - Not at all important
    - Low importance
    - Neutral
    - Important
    - Very important
19. How important are the environmental impacts of your trip for you when choosing a type of transport mode (transport mode = type of transport e.g. bus, plane etcetera)?
    - Not at all important
    - Low importance
    - Neutral
    - Important
    - Very important
20. Sort the following characteristics of journeys in order of importance to you with 1 being most important and 3 being least important

    Environmental impacts – Travel Time - Price

    1.
    2.
    3.

21. To what extent do you agree with the following statement: I believe that replacing air travel by travelling by train contributes positively to the environment.
    - Strongly disagree
    - Disagree
    - Neither agree, nor disagree
    - Agree
    - Strongly agree

Appendix 2

Correlation matrix.

	Log WTP	**Importance price**	**Importance env.**	**Pos. att. Train to Environment**
Age	0.244	-0.403	0.155	0.062
Gender	0.036	-0.033	-0.246	-0.096
Log travel time	0.136	0.000	0.000	0.000
Employed FT	-0.165	-0.246	-0.113	0.015
Importance price	-0.212	1.000	-0.272	-0.032
Importance env.	0.147	-0.272	1.000	-0.010
Importance. Travel time	-0.174	0.189	-0.124	0.051