The market potential for hyperloop

A discrete choice experiment regarding the impact of hyperloop design on preferences and mode choice for long-distance transport within Europe at Amsterdam Airport Schiphol

by

Lotte Goudswaard

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Preface

For the past six months I have been working on my master thesis as the final part of the master program Complex Systems Engineering and Management, at Delft University of Technology. This thesis was carried out in collaboration with Royal HaskoningDHV and Hardt Hyperloop.

The future of mobility is a topic that caught my interest several years ago. Over the course of my studies at Delft University of Technology this fascination has continued to grow and inspired me to write my master thesis on the impact of hyperloop design on the preferences and mode choice of people when travelling through Europe. During the time I spent writing this thesis, my interest in the topic has only deepened further.

Not only my interest in the topic kept me going during the writing process of this master thesis, but also the people that supported me during this project were a great inspiration. Therefore, I would like to thank the members of my graduation committee. Firstly, Caspar Chorus. Not only your knowledge in discrete choice modelling and your sharp mind really helped me, but also your sincere interest in how I was doing as a person during this strange time of COVID-19 was very much appreciated. Secondly, Eric Molin. Your critical feedback on my work was very useful and you really helped me to structure my thoughts during the entire project. Thirdly, I would like to thank Wijnand Veeneman. Due to your critical view, my master thesis really became a CoSEM worthy project, in which the stakeholders were taken into account.

I also would like to thank Marson Jesus from Royal HaskoningDHV. Your constructive feedback and our (almost) weekly Zoom-meetings were very useful, especially during this time of working from home. Lastly, I would like to thank Stefan Marges from Hardt Hyperloop. You always took the time to share your deep knowledge on hyperloop with me. This really helped me during my entire project and was very much appreciated.

Lotte Goudswaard
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Summary

Amsterdam Airport Schiphol (AAS) is the third largest airport in Europe in terms of passenger volumes and has been growing rapidly over the past years. This growth is expected to continue in the future (KiM, 2018). Due to the rapid growth in travel demand, AAS reached the maximum allowed number of flight movements of 500.000 per year in 2018 (Schiphol Group, 2018a). According to an Environmental Impact Assessment (EIA) carried out by Schiphol Group (2018), growth to 540.000 flight movements per year in the period of 2020-2023 is possible without violating current restrictions on noise nuisance and emissions. This number of 540.000 flight movements per year also represents the maximum number of flights that can be safely handled at AAS without further expansion and will soon be reached as well[1] (Schiphol Group, 2018a). In the case of WLO scenario high, more than a quarter of the passenger demand in 2050 cannot be handled at AAS without violating set restrictions (CPB & PBL, 2015). AAS wants to maintain its leading position in the European transport market and wants to deal with the growing passenger demand, while staying within the set restrictions in terms of the number of flight movements per year.

In order to deal with the expected increase in travel demand for long-distance travel in the future, AAS is considering alternative ways of transport and aspires to become the multimodal hub of Europe. To realize this, the focus of AAS is on short-haul flight substitution within Europe by HSR or by innovative modes. The hyperloop, initially introduced by Elon Musk (2013), is one of the innovative modes being considered by AAS and the Dutch Government (Ministery of Infrastructure and Water Management, 2020). Hyperloop consists of pods travelling through a tube, propelled by magnetic levitation, while maintaining a partial vacuum in this tube (Musk, 2013).

The literature on hyperloop has focused on the different technical aspects and the technical feasibility of hyperloop (Gkoumas & Christou, 2020a, 2020b), others highlight the energy consumption, and some criticize hyperloop for not being feasible, but nobody has examined to what extent HPT can function as substitute for short-haul flights and which role HPT could play in the future of multi-modal transport.

The aim of this study is to design the future transport system of hyperloop passenger transport (HPT) in the transport market with air passenger transport (APT), highspeed rail (HSR) and HPT for long-distance travel within Europe and to assess whether or not the passenger demand in WLO scenario high can be met, including the share of passengers that cannot be dealt with by means of APT alone. The methodology this thesis has used is discrete choice modelling (DCM). Trade-offs and mode choice of passengers when choosing between APT, HSR and HPT are analysed in order to assess the impact of different system designs of HPT on the potential of HSR and HPT in the substitution of short-haul flights at AAS. A stated preference (SP) experiment has been carried out in order to collect choice data. The focus of this study is solely on substitution of flights at AAS with both origin and destination in Europe, i.e. OD-substitution, and examines destinations that are located approximately 500 km from AAS. Substitution of transfer passengers, both within Europe and for intercontinental destinations, is disregarded in this study.

The second research objective this study seeks to address is a methodological research objective. The aim is to examine the impact of using images in the presentation of unfamiliar alternatives in the introduction of the SP experiment on preferences, attitude and drop-out of respondents. Based on these two research objectives, the following research questions have been defined:

[1] In this the current COVID-19 pandemic is not taken into account. The impact of this pandemic on long-distance travel demand remains unclear.

1. *How could different design scenarios for hyperloop passenger transport influence traveller's mode choice between, and the transport demand for, air passenger transport, highspeed rail, and hyperloop passenger transport for the future long-distance transport market within Europe at AAS?*

2. *What is the impact of the way in which HPT is introduced in the stated preference experiment on preferences, attitude and drop-out of respondents?*

Research objective 1

Methodology

To answer the first research question, a stated preference (SP) experiment was carried out among air transport passengers that have travelled from AAS in the past 5 years. Before doing so, interviews were conducted with the most important stakeholders in order to gain insights into the main design uncertainties for the system design of HPT. Three main design uncertainties came forward: the location of the HPT station, the type of security checks that should be included, if at all, and the question whether baggage check-in should be included in the design in or not. These three design uncertainties form the basis for the construction of the SP experiment. In the SP experiment respondents were asked to choose between APT, HSR and HPT in nine choice situations. These choice situations were varied in terms of the following attributes: travel cost, in-vehicle time, egress time, waiting time (varied only for HPT) and whether or not baggage can be checked-in. Also questions regarding the perceptions of respondents towards APT, HSR and HPT were included. As were questions regarding respondents' socio-demographics, survey experience and HPT understanding. Data was collected by means of an online survey panel. After the cleaning and coding of the data, both a Multinomial Logit (MNL) model and a panel Mixed Logit (ML) model were estimated.

Key Findings

By estimating the choice models, the influence of the different aspects of a journey on travelers' mode choice when choosing between APT, HSR and HPT becomes clear. In the final panel ML model, the following results were found. Firstly, the influence of travel cost was studied. Travel costs turned out to be the most important factor in passenger decisions on the preferred transport mode. Keeping ticket prices low is thus of large importance if one wants to make APT, HSR or HPT more attractive for long-distance transport in Europe.

Secondly, the role of in-vehicle time in travellers' preference and mode choice was assessed. For APT in-vehicle time was found to have a quite substantial and negative influence on travellers' preference for APT. Longer travel times thus make APT less attractive for travellers. For HSR and HPT on the other hand, only very small and not significant values were found. No hard conclusions can thus be drawn regarding the influence of in-vehicle time in the preference for HSR or HPT.

Wating time was also included in the experiment. Waiting time has been defined as the time that travellers need to wait before or in between the different components of the trip, due to e.g. security checks, checking-in their baggage, walking at the station/airport or the time that travellers arrive at the station/airport before departure of their trip. It was found that travellers' value additional waiting time, for example caused by security checks, negatively for HPT. Longer waiting times thus make HPT less attractive for travellers. If one wants to make HPT more attractive, minimizing or shortening waiting time would thus be wise to focus on.

Additionally, the influence of egress time, the time to get from the station/airport of arrival to the final destination, was studied. Only for APT significant results were found for egress time. If APT is thus located further away from the final destination, this would make APT less attractive. However, for HSR and HPT very small and insignificant parameters estimates were found. No hard conclusions can thus be drawn regarding the role of egress time of HSR and HPT in travellers' preferences.

The last attribute that was varied in the choice experiment was whether or not baggage is checked in. It was found that travelling with checked-in baggage makes APT, HSR and HPT more attractive for travellers compared to the situation when travelling with checked-in baggage is not possible. If one wants to make travelling by means of APT, HSR and HPT more attractive, including the option to have checked-in baggage is thus of large importance. When comparing the utility contribution of having check-in baggage for the three modes, it can be seen that for APT having check-in baggage leads to a substantially larger increase in utility than for HSR or HPT. For APT having the option to have checked-in baggage is thus of larger impact on the attractiveness of that mode, when looking from a user perspective, than for HSR of HPT.

Not only parameters for the included attributes were estimated in the DCM but also constants for both HSR and HPT were included in the panel ML model. After correcting the ASCs for both HSR and HPT that were found in the panel ML base model for the differences in attributes and attribute levels among the different alternatives, inherent preferences for HSR and HPT were found. It was found that if APT, HSR and HPT would be valued exactly the same in terms of observed factors and were varied in terms of the same attributes and attribute levels in the choice experiment, then APT would be chosen over HSR, while HPT would be chosen over APT.

Moreover, various perceptions towards mode-specific characteristics of HSR and HPT were included in the choice model. Travellers that see HSR and HPT as more environmentally friendly and more comfortable are more likely to pick these modes of transport than travellers that perceive HSR and HPT as less environmentally friendly and less comfortable. HSR and HPT are seen as being relatively similar in terms of these characteristics. Whether HSR and HPT are seen as more frequently departing modes, is only of small impact on travellers' preferences. This is an interesting outcome given that the high frequency for HPT is put forward as one of the unique selling points of HPT.

Besides that, the extent to which travellers perceive HSR to be reliable has a quite substantial impact on the attractiveness of HSR, while for HPT reliability only has a very small influence on preferences of travellers.

Lastly, feeling of speed and safety are both only of small influence on the attractiveness of HSR and HPT. Travellers that see HSR and HPT as modes with a high feeling of speed and as safe modes, only find HSR and HPT slightly more attractive than travellers that perceive the feeling of speed to be low and see HSR and HPT as less safe modes. Seeing a mode as safer leads to similar increases in utility, when comparing HSR and HPT, while for feeling of speed a larger difference was found between these two modes.

It was also assessed whether heterogeneous groups could be defined among respondents based on their socio-demographic characteristics. People travelling for leisure purposes, people with a higher income and people with a higher level of education turned out to find HPT and HSR more attractive that people travelling for business purposes, than people with a lower income and than people with a lower educational level. Heterogeneous groups can thus be defined among travellers.

Lastly, it was analysed whether HPT is seen as more similar to APT than to HSR. It was found that HPT is seen as more similar to HSR than to APT and therefore is more in competition with HSR than with APT. This was also confirmed by comparable utility contributions for HSR and HPT for the attributes that were varied in the choice experiment and by comparable perceptions of travellers towards some of mode specific characteristics of HSR and HPT.

HPT design scenarios

The aim of this thesis is to assess the impact of different design scenarios of HPT on travellers' preferences and mode choice, and on travel demand for APT, HSR and HPT for long-distance transport within Europe. Based on the stakeholder interviews that were conducted, three main design uncertainties for the design of the HPT system have been identified: the location of the HPT station, the type of security checks that should be included, if at all, and whether or not baggage can be checked in. These design uncertainties form the basis for the construction of different HPT design scenarios. The impact of four different HPT design scenarios on the market shares for APT, HPT and HSR was assessed: HPT as the faster HSR, HPT as the sustainable plane, HPT as a completely new system and HPT as part of the multimodal hub AAS. The stakeholder dynamics in each scenario were also studied. Aim of doing so was to assess whether there is alignment or disconnect between the design scenario that is most preferred from a traveller perspective and the scenario that is most likely from a stakeholder perspective.

The first scenario (HPT as the faster train) in which HPT is located at a new location, no security checks are in place and baggage cannot be checked in, and the forth scenario (HPT as part of the multimodal hub AAS) in which HPT is located at AAS, security check light is in place and baggage can be checked-in, were found to be the preferred scenarios from a user perspective, leading to the largest potential market share for HPT of respectively 43.0% and 40.9%. However, when considering the HPT as the faster HSR-scenario from a stakeholder perspective, a disconnect comes forward between what is likely to happen from a stakeholder perspective and what is preferred from a travellers' perspective. When locating HPT at a new location, the Municipality of Haarlemmermeer, the Province of Noord-Holland and the MRA need to be on board. An entirely new location for HPT has a substantial impact of its surroundings and the environment, which could lead to complications in terms of stakeholder coalitions that need to be formed. Locating HPT at AAS is thus more likely to happen from a stakeholder perspective. Which is the case in design scenario 4, HPT as part of multimodal hub AAS, leading to less complicated stakeholder dynamics and making this design scenario thus more likely to happen. In terms of the location of the station a slight disconnect was thus found between what is most preferred from a traveller perspective and what is most likely from a stakeholder perspective, since a new location is preferred from a user perspective but is considered less likely from a stakeholder perspective. In terms of security checks and baggage handling, no issues are expected in terms of stakeholder coalitions.

Besides that, it was studied whether the expected surplus increase in travel demand of 26.6 million OD passengers at AAS could be dealt with by adding HPT to the transport market. In all four design scenarios it was found that the surplus in travel demand that has been predicted for WLO scenario high can be dealt with.

Research objective 2

Methodology

Two different versions of the introduction were included in the survey, one version with a text-only explanation of HPT and the other version with both text and images of HPT. Both versions of the introduction were randomly assigned to the respondents of the survey. Both the DCM and independent sample t-tests were used to answer the research question of this second research objective. In the end, almost an equal number of respondents completed the survey for both versions of the introduction.

Key findings

The drop-out rate was slightly bigger for people receiving the text and images introduction, but the difference is almost negligible. When considering the impact of the version of the introduction on preferences, no influence of using images in the introduction of the SP experiment of HPT on the choice behaviour of respondents was found. Additionally, no influence on the use of images in the introduction of the choice experiment on drop-out rate was found.

The impact of the different versions of the introduction on respondents' understanding of HPT was also studied. A significant difference was found between the group of respondents that received the text only introduction and the group of respondents that received the introduction with both images and text in terms of how clear they experienced the explanation of HPT and of how complete they perceived their image of HPT to be. Respondents that received the version of the introduction with both images and text were found to experience the explanation as clearer, with a more complete image of HPT as a result.

Also, substantive questions on information on HPT that was provided in the introduction were included in the survey. One question was asked on the propulsion of HPT and the other question was whether can look outside when travelling by means of HPT. Based on the chi-square test that was performed, it came forward that a significant difference between the group of respondents that received the text only introduction and the group of respondents that received the introduction with both images and text, in how the two substantive questions were answered. Including both images and text in the introduction of the choice experiment thus led to respondents answering the substantive questions more correctly.

In conclusion: if one wants to reduce the drop-out rate during SP experiments, using both images and text in the introduction of the choice task might not be the way to achieve that. However, using images díd improve the understanding of HPT by respondents. Using images to explain something people are unfamiliar with, thus can be helpful to improve understanding of that concept. This insight is useful for scientific purposes but can also be applied outside the world of science.

Lastly, the impact of the different versions of the introduction on whether respondents see HPT more similar to APT or to HSR was analysed. When considering both nesting structures and both data sets based on the different versions of the introduction, it was found that HPT is seen as more similar to HSR by people who received the introduction with both images and text compared to people who received the text only introduction. How a certain mode looks thus could play a role in its positioning compared to other modes of transport and potentially impacts its competitive position.

Wider implications of this thesis

The results that were found in this thesis have wider implications for policy, for stakeholders and for society. Policy advice can be formulated, mainly applicable for the key stakeholders: the HPT developer (Hardt Hyperloop in this thesis) and the airport operator (AAS in this thesis). It was found that **HPT is seen as more similar to HSR and thus is more in competition with HSR than with APT**. If the aim of introducing HPT is to merely reduce APT demand, striving for a transport market for long distance transport that is dominated by HPT and HSR, HPT might not be the right mode to facilitate this shift to land based modes. APT remains a popular mode for long distance transport and as long as no policy measures are taken to make APT less attractive, this will continue to be the case. European policies have a key role to play in making APT less attractive. Incorporating the environmental cost of travelling by means of APT in the ticket prices of APT, is a key component for such a policy.

Moreover, it was found that travellers that see HPT as more **comfortable and more environmentally friendly** find HPT more attractive. Additionally, the high **frequency** of HPT is often put forward as one of its main selling points by HPT developers. However, it was found that whether or not travellers perceive HPT to be a frequently departing mode, only has a small influence on the attractiveness of HPT. Either the marketing of HPT should focus strongly on the high frequency of HPT and, more specifically on making sure that travellers know why this high frequency is really beneficial for them, or HPT developers should redirect their focus to other strong aspects of HPT in their marketing.

Besides that, this research shows that **leisure travellers**, travellers with a **higher income** and travellers with a **higher educational level** find HPT to be more attractive than business travellers, travellers with a lower income and travellers with a lower educational level. The HPT developer should therefore be highly aware of the type of travellers that find HPT an attractive mode of transport. He could either focus on attracting this first group even more or focus on diversifying its travellers among passengers in the second group. Both strategies require different steps from a marketing perspective.

Additionally, in terms of the HPT design, the HPT developer should focus on minimizing **waiting time** for HPT, given the large impact of waiting time on the attractiveness of HPT from a travellers' perspective. When locating HPT at the airport it thus is important that the airport operator is willing to facilitate minimizing the waiting time of HPT. This could also benefit the position of the airport as multi-modal hub and could increase the total number of passengers travelling via the airport, which is beneficial for the airport operator. Additionally, if the HPT developer and the airport have the ambition to also transport **transfer passengers**, this would be easier to do when HPT is located at the airport, while in order to attract more OD passengers, locating HPT more closely to the city is more logical. HPT developers thus needs to make further trade-offs in whether they want to optimize their system for OD passengers or whether they choose to design the system also taking transfer passengers into account.

An implication regarding the **current HSR transport system** for long-distance travel can also be given. From the stakeholder interviews that were conducted is became clear that in order to strengthen the HSR system, European cooperation needs to be sought regarding ticket integration, marketing of HSR needs to be improved and introducing checked-in baggage in HSR should be considered. These three issues appear to be highly relevant for the future role of HPT as well.

Recommendations

Research objective 1

Four recommendations for further research are made. The first recommendation would be to include other modes, such as conventional cars, autonomous cars and night trains, in the experiment. Secondly, travel distances other than 500 km should be researched. Thirdly, the perceptions regarding the different modes were only measured based on one question. Perceptions could be measured more precisely by adding multiple questions for each perception. Forthly, the influence of the introduction of HPT on the total travel demand should be studied, given that the introduction of HPT could also induce new demand. The extent to which the introduction of HPT leads to additional demand should thus be studied. Besides that, it is recommended to study whether working with a larger group of respondents that was not merely recruited by means of an online panel, leads to different results than those found in this study. Lastly, the influence of the different HPT scenarios on the potential market shares for APT, HSR and HPT were based on the MNL model. Given that this model does not take into account that HSR and HPT are more in competition with each other, the influence of the different design scenarios should be assessed by means of the panel ML model.

Research objective 2

Three recommendations can be made for this research objective. Firstly, it could be studied whether more respondents for each version of the introduction would lead to different results. Secondly, only a distinction between a version of the introduction with only text and a version with both images and text is made in this thesis. More means of communication could be used in the introduction, for example using virtual reality as well. Lastly, it could be assessed whether preferences for certain types of introductions, using different types of media are preferred by specific groups or for specific research objectives.

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1. Introduction

Amsterdam Airport Schiphol (AAS) is the third-largest airport in Europe in terms of passenger volumes and has been growing rapidly over the past years. This growth is expected to continue in the future (KiM, 2018)[2]. In 2017 68,5 million passengers were handled at AAS, which is a 7,7% growth in the number of passengers compared to 2016 (KiM, 2018). In 2019 AAS handled 71.1 million passengers, which implied growth of 0,9% compared to 2018 (Royal Schiphol Group, 2020). This growth of the number of passengers handled at AAS is mainly due to large growth in travel demand for long-distance travel, i.e. journeys longer than 100 km, within Europe[3] (van Goeverden, Milakis, et al., 2018). Currently, these types of journeys are primarily made by air passenger transport (APT) and to a lesser extent by highspeed rail (HSR) (Gkoumas & Christou, 2020a; van Goeverden, Janic, et al., 2018).

Due to the rapid growth in travel demand, AAS reached the maximum allowed number of flight movements of 500.000 per year in 2018 (Schiphol Group, 2018a). According to an Environmental Impact Assessment (EIA) carried out by Schiphol Group (2018), growth to 540.000 flight movements per year between 2020 and 2023 is possible without violating current restrictions on noise nuisance and emissions. This number of 540.000 flight movements per year also represents the maximum number of flights that can be safely handled at AAS without further expansion and will soon be reached as well[4] (Schiphol Group, 2018a). To deal with the expected increase in travel demand for long-distance travel in the future, AAS is considering alternative ways of transport and aspires to become the multimodal hub of Europe. To realize this, AAS is exploring modal shift policies such as short-haul flight substitution of flights within Europe by HSR or by innovative modes. The reason for also considering innovative modes is that HSR is currently not considered to be attractive enough from a user perspective. Also, several challenges from the perspective of the rail sector remain. From a user perspective longer travel times, information provision on trips and tickets, and the fact that tickets often become available only three months in advance, form the main bottlenecks to use HSR more often. For the rail sector mainly the lack of an integral and international approach is in the way of more success of HSR. Innovative modes could potentially meet these shortcomings of HSR and are therefore taken into consideration as well (Raad voor de Leefomgeving en Infrastructuur, 2020; Schiphol Group, 2018b).

The Netherlands Bureau for Economic Policy Analysis (CPB) and the Netherlands Environmental Assessment Agency (PBL) (2015) constructed future scenario's (WLO (Welvaart en Leefomgeving) scenario's) in which the growth of passenger demand at AAS for 2050 is predicted. In WLO scenario low, the passenger demand at AAS is said to be 110 million passengers in 2050, in WLO scenario high the number of passengers is predicted to be 170 million passengers in 2050 (CPB & PBL, 2015). However, the number of passengers that could be dealt with at AAS is being limited by the number of allowed flight movements. In WLO scenario low, the passenger demand in 2050 can be met within set restrictions to limit the environmental impact of AAS, due to technological innovations that make APT more sustainable. In the case of WLO scenario high, more than a quarter of the passenger demand in 2050 cannot be handled at AAS without violating set restrictions (CPB & PBL, 2015). AAS wants to maintain its leading position in the European transport market and wants to deal with the growing passenger demand while staying within the set restrictions in terms of the number of flight movements

[2] In this, the current COVID-19 pandemic is not taken into account. The impact of this pandemic on long-distance travel demand remains unclear.
[3] In this, the current COVID-19 pandemic is not taken into account. The impact of this pandemic on long-distance travel demand remains unclear.
[4] In this, the current COVID-19 pandemic is not taken into account. The impact of this pandemic on long-distance travel demand remains unclear.

per year. Considering this aim, AAS seeks to strengthen its position as a multi-modal hub by improving connections at AAS over land and therefore is interested in substitution of short-haul flight within Europe by HSR or by innovative modes (Schiphol Group, 2018b). By doing so, the number of short-haul flights can be reduced and AAS can focus on optimizing its intercontinental operations (KLM, 2018).

Hyperloop, initially introduced by Elon Musk (2013), is one of the innovative modes being considered by AAS and the Dutch Government (Ministery of Infrastructure and Water Management, 2020). Hyperloop consists of pods travelling through a tube, propelled by magnetic levitation while maintaining a partial vacuum in this tube (Musk, 2013). Therefore, air resistance and drag are almost eliminated completely, allowing for an expected speed close to 1000 km/h and limiting energy consumption. Energy used will be green energy and hyperloop is expected to mostly offer an alternative for journeys up to 1500 km, now primarily made using APT and HSR (Gkoumas & Christou, 2020a; van Goeverden, Janic, et al., 2018). Two types of hyperloop can be distinguished, one exclusively for passenger transport and the second type mixing passenger transport and freight transport (van Goeverden, Milakis, et al., 2018). This thesis will focus on hyperloop passenger transport (HPT) exclusively.

The literature on hyperloop has focused on the different technical aspects and the technical feasibility of hyperloop (Gkoumas & Christou, 2020a, 2020b). Furthermore, the societal impact of the introduction of HPT has been researched by various studies (Hansen, 2020; Janić, 2019; Leibowicz, 2018a; van Goeverden, Janic, et al., 2018; van Goeverden, Milakis, et al., 2018; Werner et al., 2016). A challenge concerning HPT that remains is the issue of (perceived) safety by users, as transport takes place through a tube at a high speed (Hansen, 2020). In the field of policies, challenges also remain for HPT (Leibowicz, 2018; Werner et al., 2016). Furthermore, the feasibility of the concept of hyperloop is being criticized (Beens, 2020; van de Weijer, 2020). However, while several studies focus on the technical feasibility, others highlight the energy consumption, and some criticize hyperloop for not being feasible, but nobody has examined to what extent HPT can function as a substitute for short-haul flights and which role HPT could play in the future of multi-modal transport.

The aim of this study is to design transport system of HPT in the transport market with APT, HSR and HPT for long-distance travel within Europe and assess whether or not the passenger demand in WLO scenario high can be met, including the share of passengers that cannot be dealt with by means of APT alone. Thereby this study seeks to address travellers' trade-offs and mode choice when choosing between APT, HSR and HPT. By doing so, the potential of HSR and HPT as a means to substitute short-haul flights within Europe is studied. The impact of different system designs of HPT on mode choice and trade-offs of travellers is analysed. Also, the likelihood of the formation of the needed stakeholder coalitions, for the different design scenarios, is studied. By doing so, it becomes clear whether the travellers' perspective on the system design of HPT, based on traveller's mode choices, aligns with the most likely design scenario's in the light of the needed stakeholder coalitions.

The methodology this thesis has used is discrete choice modelling (DCM). DCM is a statistical method to assess how people, often travellers, make choices between different modes, to understand and predict choices people make (de Dios Ortuzar & Willumsen, 2011). Therefore, this study will apply DCM to examine trade-offs and mode choice of travellers when choosing between APT, HSR and HPT to assess the impact of different system designs of HPT on the potential of HSR and HPT in the substitution of short-haul flights at AAS. A stated preference (SP) experiment has been carried out to collect choice data. The focus of this study is solely on the substitution of flights at AAS with both origin and destination in Europe, i.e. OD-substitution. Substitution of transfer passengers, both within Europe and for intercontinental destinations, are disregarded in this study. The reason for this is that in 2017 63,2% of the passengers at AAS were origin-destination passengers, and 36,9% of the passengers were transfer passengers (KiM, 2018). Thus, the focus will be on the largest group of passengers being handled at AAS.

Insights generated in this study are relevant for both society and science. For AAS, the problem owner, insight into the potential future of AAS as a multi-modal hub and into the role HSR and HPT could play in this future, are generated. Other stakeholders such as Hardt Hyperloop and NS International could benefit from the insights this study will generate as well. For Hardt Hyperloop the influence of different systems designs on the potential market share of HPT is assessed. For NS International, the future of HSR is analysed in more detail. This thesis is carried out by order of Royal HaskoningDHV and Hardt Hyperloop. The scientific relevance of this study is not only in adding knowledge on the future of multi-modal long-distance transport but also in generating methodological knowledge on DCM combined with SP data. This will be done by including two versions of the introduction of the SP experiment of which one version will include images of HPT whilst the other version will explain HPT merely by text. The impact of including images of unfamiliar alternatives on preference, attitude and drop-out will be assessed.

1.1 Research objectives

This research addressed two objectives. The first research objective is on the impact of different design scenarios for HPT on traveller's mode-choice and trade-offs when taking APT, HSR and HPT into account. The second research objective is a methodological research objective, striving to examine the impact of including images of unfamiliar alternatives, the transport modality of hyperloop in this case, in the introduction of an SP experiment on respondents' preferences, mode choice and drop-out. This is done by including two versions of the introduction, of which one contains both text and images while the other version only contains the textual explanation.

1.1.1 Research objective 1: Hyperloop system design

The first research objective is to design the system of HPT for long-distance travel within Europe at AAS. The impact of different design scenarios for HPT on travellers' mode choice, trade-offs and transport demand will be discussed. Furthermore, the stakeholder coalitions needed in these different design scenarios and the likelihood of those coalitions to be formed will be analysed. By doing so, it becomes clear whether the travellers' perspective on the system design of HPT, based on traveller's mode choices, aligns with what design scenarios are most likely when considering the likelihood of the stakeholder coalitions to be formed. Only the transport modes of APT, HSR and HPT will be taken into consideration. In WLO scenario high, AAS will not be able to deal with a quarter of the passenger demand in 2050 in its current layout (CPB & PBL, 2015). By assessing the trade-offs and mode choice of travellers in different design scenarios of HPT, the share of flights that could potentially be substituted by HSR and HPT can be examined, and it becomes clear in which designs of HPT AAS can or cannot deal with the increase in travel demand.

Furthermore, this study is situated in a socio-technical context in which a variety of stakeholders is involved, who could all impact the design. Therefore, a stakeholder analysis is carried out to gain insights into the solution space created by the different stakeholders. The stakeholders determine the prerequisites for the design process, which, together with scientific literature, stipulates the different attributes to be included in the discrete choice experiment that will be carried out. Based on the different design options obtained from the stakeholder interviews, various scenarios of the HPT design can be constructed. Also, the stakeholder coalitions needed for the different design options of HPT and the likelihood of those coalitions to be formed will be discussed. The impact of these different designs of HPT on travellers' trade-offs and mode choice will be assessed as well. By using DCM, the user perspective on the different modes of transport is assessed in different design scenarios, focussing on mode-choice and the trade-offs made by travellers when choosing between APT, HSR and HPT.

1.1.2 Research objective 2: impact of the introduction of an SP experiment

The second research objective is to examine the impact of using images in the presentation of unfamiliar alternatives in the introduction of the SP experiment on preferences, attitude and drop-out of respondents. In this study, the data collection for the DCM is done using an SP experiment. Including an alternative into the SP experiment that respondents are unfamiliar with, such as a new mode of transport, is a more complex matter than including familiar alternatives, e.g. expanding existing transport alternatives (McFadden, 2017). When unfamiliar alternatives are included in SP experiments, the information concerning that alternative could influence respondents in their preferences. As a researcher, you on the one hand want to inform the respondents, but respondents could take the provided information as clues for desired answers on the other hand (Ben-Akiva et al., 2019). Van Langevelde-van Bergen (2019) studied this matter as well by including text and videos in the introduction of her SP experiment. No significant influence of the variation in the introduction in terms of content and communication medium was found. The study of van Langevelde-van Bergen (2019) however did show that the wording used in the introduction can influence the results of the study. It was recommended to test the impact of the different types of introductions in more studies to see if comparable results are found. Little is known about the impact of the way a new mode of transport is introduced in an SP experiment, in terms of text and communication medium used, on choices made by respondents (van Langevelde-van Bergen, 2019).

Several studies examine the influence of the communication medium used to provide information, on found preferences. For instance, Baggett(1984) studied whether visual and auditory information compared to textual information could cause a better generation of mental models of a situation than textual information. The results of this study indicate that the human brain is better at and faster in processing visual information than written text. Furthermore, both Orzechowiski et al. (2005) and Dijkstra et al. (1996) studied the application of images in choice tasks and found images to improve realism, and with this improved the validity of the found results. However, the impact of the use of images on found preferences was not studied. Therefore, this thesis will vary its introduction in the SP experiment between a version with written text only and a version with both text and images of HPT. The effect of using images could potentially improve understanding of unfamiliar alternatives. The effect of using images in the SP experiment on preferences, attitude and drop-out has not yet been studied thoroughly. This study strives to contribute to that gap in scientific knowledge.

1.2 Research questions

Departing from the articulated research objectives, the research questions and the accompanying sub-questions of this study were formulated. Seven sub-questions are defined in order to answer the first main research question and achieve the set first research objective. The second research question addresses the second research objective, without introducing sub-questions. After introducing the research questions, the research approach that will be applied to answer these questions will be discussed briefly in paragraph 1.2.1. A more in-depth elaboration on the methodology is given in chapter 3, 4 and 5. The following first research question was defined:

How could different design scenarios for hyperloop passenger transport influence traveller's mode choice between, and the transport demand for, air passenger transport, highspeed rail, and hyperloop passenger transport for the future long-distance transport market within Europe at AAS?

With the following sub-questions, supporting answering the first research question:

1. What are, according to the main stakeholders, the most important design variables for the design of the HPT system for long-distance travel in Europe?
2. Which stakeholders and potential stakeholder coalitions influence the solution space for the design of the HPT system for long-distance travel in Europe at ASS and how likely are these stakeholder coalitions to be formed?
3. What are the choice probabilities of respectively APT, HSR and HPT and to what extent do the included attributes determine the preferences of travellers when choosing between APT, HSR and HPT for long-distance travel within Europe?
4. What are the utility contributions of the different perceptions towards mode-specific characteristics of HSR and HPT and how do these impact the found preferences?
5. To what extent can heterogeneity in the sample be identified based on socio-demographic factors of respondents and what is the influence of this heterogeneity on found preference and mode choice?
6. To what extent can HPT be (partly) categorized in the nests of air transport or rail transport?

The second research question that has been defined is as follows:

What is the impact of the way in which HPT is introduced in the stated preference experiment on preferences, attitude and drop-out of respondents?

1.2.1 Research approach

The first sub-question aims at defining the design space, by gaining insights into the main design uncertainties and design challenges present in the design of HPT and by assessing the roles of different stakeholders and stakeholder coalitions in different HPT designs options. The second sub-question focuses on the stakeholder coalitions that are needed for or are involved in the design of HPT. Also, the likelihood that those stakeholder coalitions indeed will be formed, is assessed. The stakeholder interviews form an important basis in answering this sub-question. The third sub-question assesses the role of the included attributes in the preferences of travellers. This is done based on the DCM. Also, the found choice probabilities of APT, HSR and HPT are examined. Through the fourth sub-question insights are gained in the perception of travellers towards the mode-specific characteristics of HSR and HPT, and into how these perceptions are of influence on the preferences of travellers. The fifth sub-question assesses the extent to which heterogeneous groups can be identified in the sample based on the socio-demographics of the respondents. By doing so, it becomes clear whether preference differs amongst different user groups which is mainly interesting to know from a marketing perspective. The last sub-question addresses whether HPT is seen as more similar to air transport or rail transport from a travellers' perspective. Answers can be generated based on the constructed DCM, more detailed an error component model. The error term represents the variation across individuals in unobserved utility. In ML models, an extra error term can be added, representing the variation across individuals of the utility of the common unobserved factors of different alternatives. The size of this error term reflects the degree of correlation between (unobserved) factors, among alternatives (Chorus, 2018). By comparing the error term that was added to both APT and HPT and the error terms that was added to both HSR and HPT, this sub-question could be answered.

1.3 Research demarcation

To define the scope of this research, a clear research demarcation is needed. First of all, only APT, HSR and HPT are included, given that these three modes are often positioned as potentially competitive for long-distance travel. A comparison will be made among these three modes, whereas other modes of transport, such as car, or other transport innovations, such as autonomous driving or electric airplanes, are out of scope.

Secondly, this research is positioned in a situation in which COVID-19 is not in place and will assess travellers' preferences and mode-choice during the non-pandemic circumstance. Respondents will be asked to make their choices under the assumption that the current COVID-19 pandemic is over.

Thirdly, the geographical area under study is Europe, considering flights leaving from AAS with a destination within Europe only.

Fourthly, the focus is on the possible substitution for short-haul flights departing from AAS by HSR and HPT for the current travel demand, not taking into account the fact that the improved accessibility due to HSR or HPT could induce more transport demand. The level of substitution can become clear by analysing the differences in market shares before and after changes in the transport market (Kroes & Savelberg, 2019). Additionally, since 63,1% of the passengers travelling at AAS had both their origin and destination within Europe, only OD-substitution is taken into account, leaving substitution of transfer flights out of scope (KiM, 2018).

Lastly, the focus will be on the currently hypothetical situation in which the hyperloop is an existing mode of transport in Europe. This is defined as the exploitation phase. The innovation phase, in which hyperloop is developed, and the realisation phase, in which infrastructure would be built, will thus not be included (Hardt Hyperloop, 2020). Respondents will be asked to choose between APT, HSR and HPT assuming HPT would be reality now. The research is positioned in 2021, since people are not able to make choices in the future, e.g. the imaginary situation of 2050. This will also be stated clearly in the introduction of the SP experiment.

1.4 Relevance of this research

This section provides insights into the relevance of this thesis for society, for science and for the master program of Complex Systems Engineering and Management (CoSEM).

1.4.1 Societal relevance

Generating insights on the future transport market for long-distance travel is relevant to society, as transport forms a vital element of society. Being able to deal with transport demand at AAS in the future not only impacts the mobility of Dutch citizens but also benefits the Dutch economy. Besides that, a wide variety of stakeholders is involved or interested in the outcomes of this research. Stakeholders that could use the outcomes of this research would be AAS (problem owner), the Dutch Railway company (NS), companies developing hyperloop technology such as Hardt Hyperloop (client), companies advising on the future of transport such as Royal HaskoningDHV (client), and both the Ministry of Infrastructure and Water Management and the Ministry of Economic Affairs and Climate Policy. Furthermore, knowing whether or not, and in what design scenario of HPT, people are willing to substitute their current short-haul flights by HSR or HPT, is useful information for policymakers as well. The recently published vision on the future of the aviation industry by the Dutch Ministry of Infrastructure and Water Management (2020) also focuses on the potential role of HSR and innovative modes as HPT in order to reduce flight emissions. This thesis could contribute to concretising the potential of this for achieving these policy goals. To conclude, due to both the stakeholder incorporation and the policy implications, this thesis is relevant for society.

1.4.2 Scientific relevance

Both the role of HSR in short-haul flight substitution and HPT technology both have been studied, but no research has yet been conducted on a transport market in which APT, HRS and HPT are combined, applying DCM (Hansen, 2020; van Goeverden, Milakis, et al., 2018). By doing so, this thesis will thus contribute to the body of knowledge of the future of long-distance travel and the potential role of HSR and HPT in it. Additionally, a very limited body of literature is available on the extent to which the way of introducing a new mode in an SP experiment is of impact on found preferences, mode choice and drop out. Van Langevelde-van Bergen (2019) found that wording in the introduction matters, however no significant results on the information provided and the communication medium used were found. By studying the impact of the use of images on found preferences, attitude and drop-out and by assessing the impact of HPT design on mode-choice and preferences when choosing between APT, HSR and HPT, scientific knowledge is added by this thesis.

1.5.3 CoSEM relevance

A CoSEM engineer distinguishes herself from other engineers by focussing on innovations and their surrounding socio-technical system and by not just considering technology alone (Delft University of Technology, n.d.). In this socio-technical system, institutions, stakeholders, technology and economy are in place and all need to be considered in decision-making.

Transport systems are often positioned as complex socio-technical systems, due to both the technical and social aspect, respectively the transport technology and the humans using the transport system. While changes in the transport market for long-distance travel affect a lot of stakeholders, the potential substitution of APT by HSR or HPT could have consequences for the economy as well. With better connectivity and faster connections, distance and thus national borders will matter less. This enlarges the economic area within reach substantially and changes the competitive environment. Lastly, institutions are crucial to realize change. For the transport market to change and to substitute short-haul flights, institutions and policies are crucial. Therefore, this study is conforming to the CoSEM standards, making it applicable for a CoSEM thesis.

1.5 Report outline

In chapter 2, literature reviews will be carried out for both research objective, in order to identify the existing knowledge gaps in the literature. After that, the methodology of discrete choice modelling is discussed in more detail in chapter 3. Chapter 4 addresses the main design uncertainties in the HPT system design, based on various stakeholder interviews. With these design uncertainties in mind, the survey is designed. This is discussed in chapter 5. In chapter 6 the data collection and sample characteristics are discussed, followed by the methodology that was used to analyse this data, in chapter 7. The results regarding the first research objective will be discussed after that and can be found in chapter 8. In chapter 9 the methodology and result of the second research objective are discussed. In chapter 10 the impact of the different HPT design scenarios is discussed in more detail. Lastly, a conclusion, the wider implications of this thesis and the discussion can be found in chapter 11.

2. Literature study

In this chapter two scientific literature reviews are carried out to gain insights into the status quo of the literature in the field of the two research objectives. In paragraph 2.1 a literature review on short-haul flight substitution is presented, followed by the literature review on the role of information provided and the communication medium used in the introduction of an SP experiment on preferences, in paragraph 2.2. In each section first a comparison of the selected articles is presented, after which the knowledge gaps this thesis seeks to address are articulated.

2.1 Literature review short-haul flight substitution (research objective 1)

Short-haul flight substitution is a topic that has been researched widely over the past years, mainly focussing on the potential of HSR. Besides that, the body of literature on HPT has also been growing. First, the applied methodology in conducting this literature review is presented in paragraph 2.1.1. The status quo of scientific literature concerning the role of HSR and HPT in short-haul flight substitution is presented in paragraph 2.1.2. In paragraph 2.1.3 the applicability of DCM on these types of topics is discussed, followed by the identified knowledge gap this thesis seeks to address, presented in paragraph 2.1.4.

2.1.1 Methodology

To identify the knowledge gaps that are present in scientific literature, several questions have been identified. Based on the answers to those questions and their accompanying knowledge gaps, the first knowledge gap this thesis seeks to address, has been identified. An overview of the included articles and the applied search strategy can be found in *Appendix A*. The following questions have been identified. The number between brackets behind each question indicates the paragraph in which the question is discussed.

- What has already been studied concerning the future transport market for long-distance travel? (2.1.2)
- What has already been researched in terms of the role HSR could play in short-haul flight substitution? (2.1.2)
- What has already been researched with respect to the impact of HPT on APT demand? (2.1.2)
- What has already been studied in terms of the transport market with APT, HSR and HPT? (2.1.2)
- What has already been studied in the field of HPT system design? (2.1.2)
- What has already been studied in terms of the trade-offs and mode choice of travellers for long-distance transport? (2.1.3)
- What has already been researched in terms of the impact of the introduction of HPT on travellers' trade-offs and mode choice? (2.1.3)
- What are the main knowledge gaps that remain concerning the future market for long-distance transport? (2.1.4)

2.1.2 Transport market

The future transport market for long-distance travel has been widely studied in scientific literature, mainly focussing on either the impact of HSR on APT demand (Behrens & Pels, 2012; Chiambaretto & Decker, 2012; D'Alfonso et al., 2016; Dobruszkes et al., 2014; Kroes & Savelberg, 2019; Nash, 2015; Takebayashi, 2014; Terpstra & Lijesen, 2015), on the potential influence of HPT on APT demand (Decker et al., 2017; Janić, 2019; van Goeverden, Janic, et al., 2018) or on the transport market with APT, HSR and HPT (Hansen, 2020; Rajendran & Harper, 2020; van Goeverden, Milakis, et al., 2018). Besides that, various studies were conducted merely focussing on HPT technology and its implications (Gkoumas & Christou, 2020a; Leibowicz, 2018b).

Kroes & Savelberg (2019) studied the potential of HSR in OD-substitution of short-haul flights at AAS using DCM and found that HSR could potentially reduce the number of flights at AAS in 2030 by 2,5% to 5%. To achieve this, rail travel times and ticket prices need to be reduced and service frequencies and level of comfort need to be increased. They state that short-haul flight substitution plays a crucial role in making transport more sustainable. However, Nash (2015) found that substituting air travel with HSR has only potential for travel distances shorter than 800 km, indicating a travel time of less than six hours. Nonetheless, D'Alfonso et al. (2016), who focused on the environmental impact of competition between HSR and APT, found a negative net effect of the introduction of HSR due to the induced demand as a consequence of HSR. In terms of competition between HSR and APT for transfer substitution, Takebayshi (2014) found HSR to be dominant when connections between HSR and APT through cooperation are good, improving international passengers welfare. To achieve that, a commercial incentive is in place for airlines to cooperate with HSR, however, for HSR there is less need to collaborate with the airlines. This cooperation will mainly benefit transfer passengers. Dobruszkes et al. (2014) and Chiambaretto & Decker (2012) also studied the competition between HSR and APT. They found that shorter travel times for HSR lead to less demand for APT on those trajectories. However, for journeys with a travel time longer than 2 to 2,5 hours the dominance of HSR becomes limited. The impact of frequency was found to be limited (Dobruszkes et al., 2014).

Also, various studies have been conducted studying the competition between HPT and APT. HPT is often presented as an alternative, more sustainable, mode of transport, potentially meeting the shortcomings of APT and/or HSR for long-distance passenger transport (Decker et al., 2017; Hansen, 2020; Janić, 2019, 2020; van Goeverden, Janic, et al., 2018; van Goeverden, Milakis, et al., 2018; Voltes-Dorta & Becker, 2018). Decker et al. (2017) found that HPT is a more suitable mode than APT for current short-haul flights and thus has the potential to substitute these flights and reduce transport emissions. However, Janic (2019) and van Goeverden, Janic et al. (2018) are less optimistic on this, mainly due to the high infrastructure cost, the environmental burden related to building new infrastructure and the assumed capacity of 28[5] passengers per vehicle. HPT is said to be the expensive competitor of APT. Janic (2019) studied the competitive capabilities of HPT with respect to the current and future APT system and the potential to mitigate environmental and societal impacts related to that. He found that HPT can potentially compete with conventional APT, but when APT becomes more sustainable and innovative, the demand for HPT will drop rapidly. The main issues for HPT are most likely to occur during implementation. After implementation, HPT has the potential to become comparable to APT in environmental and social terms (Janić, 2020). Van Goeverden, Janic et al. (2018) also focused on the energy consumption and environmental impact of a fully developed HPT network compared to APT. They found was that introducing HPT could lead to a reduction of emissions and energy consumption, hence these reductions will be almost negligible due to the demand that will be induced by HPT.

Furthermore, the transport market with APT, HSR and HPT has been studied. A comparison of the three systems has been made by Hansen (2020), taking the functional designs, the aims, the transport capacity and the expected demand into consideration. For HPT to be competitive with APT

[5] By HPT developers, the current capacity of HPT is said to vary between 28 and 60 passengers per pod. A capacity of 28 passengers for each pod is the capacity that was initially proposed in the Alpha Paper by Elon Musk (2013) and is what was assumed by these papers.

and HSR for long-distance travel, HPT needs to compete with APT in terms of travel times and comfort and needs to have a lower environmental burden and needs to have a lower energy consumption. On the other hand, in comparison with HSR, a sufficiently high transport capacity of HPT needs to be realised to deal with travel demand at a lower investment cost than HSR. Furthermore, Hansen (2020) argues that travel time reduction of HPT due to the high speed could be diminished considerably when security checks and gate controls become too time-consuming, which is important to keep in mind when designing the system (Hansen, 2020). When only considering the operation of HPT compared to APT and HSR, a positive social and environmental impact was found by van Goeverden, Milakis et al. (2018), due to the low energy use and almost neglectable noise pollution. However, HPT is found to have disadvantages in terms of operational and financial performance and in terms of safety performance. Further research on those aspects is recommended (van Goeverden, Milakis, et al., 2018).

2.1.3 Mode choice & trade-offs

The impact of the introduction of HPT on the trade-offs and mode choice of passengers has barely been researched in scientific literature, but it is an important aspect of this new technology (Gkoumas & Christou, 2020a). Rajendran & Harper (2020) considered the willingness to use HPT using simulation models but did not provide insights into the impact of the introduction of HPT on passengers' trade-offs when choosing between APT, HSR and HPT. Several publications on the impact of the introduction of HSR on the current APT system from a passenger perspective were found (Dobruszkes et al., 2014; Kroes & Savelberg, 2019; Terpstra & Lijesen, 2015), often by means of DCM (Behrens & Pels, 2012; Bergantino & Madio, 2020; Kroes & Savelberg, 2019; Román & Martín, 2014; Terpstra & Lijesen, 2015; Voltes-Dorta & Becker, 2018). However, the methodology of DCM has not yet been applied regarding the transport market of APT, HSR and HPT combined.

Román & Martin (2014) applied DCM to study the transport market of HSR and HPT, focussing on understanding passenger preferences concerning the integration of those two modes when considering transfer substitution. Schedule coordination was found to be crucial for good integration and a disutility with respect to changing modes was found. This disutility could be compensated by travel time reductions or by how connections are arranged, more than by baggage integration. Baggage integration was valued highly for leisure trips and was of less importance for business trips. However, arranging baggage integration across modes is a complex matter in terms of stakeholder collaborations. Fare and ticket integration were also found to be highly valued by respondents. Besides that, safety and punctuality were both positively associated with HSR (Román & Martín, 2014). Behrens & Pels (2012) also applied DCM and made a distinction between preferences of passengers travelling with leisure or business purposes and found the degree and pattern of competition between APT and HSR to vary considerably depending on trip purpose. Business travellers were found to value total travel time and weekly frequency more than leisure travellers and are less affected by ticket price in their mode choice. Overall, frequency, travel time and accessibility of the station/airport were found to be the main determinants of travel behaviour (Behrens & Pels, 2012). This distinction in trip purpose when applying DCM, taking both HSR and APT into account, was also made by Bergatino & Madio (2020). An increase of mode choice for HSR was found among business travellers, for distances up to 500 km. Transfer substitution was under analysis in this study, finding that substitution of APT by HSR or of the regular train by HSR are most likely to occur.

2.1.4 Knowledge gap 1

Various studies have been conducted on short-haul flight substitution and the role of either HSR or HPT in that. However, most studies focused on the substitution of transfer journeys only, not on OD-substitution. Agreement seems to be reached among researchers on the fact that HSR could provide a substitute for APT if travel times of HSR decrease. For journeys with a travel distance longer than 700 km or even for journeys with travel time longer than 2 to 2,5 hours, the potential of HSR to substitute flights is expected to decrease rapidly. Furthermore, various studies looked into the potential impact of HPT on APT demand. Several studies compared these two modes in terms of energy consumption, but ambiguous conclusions came forward. These studies argued that when considering the operation of HPT and APT, HPT could form the more sustainable alternative taking away travel demand from APT. However, when APT would become more sustainable, the demand for HPT would drop rapidly. Also, the emissions accompanying the construction of HPT have been studied, which is expected to largely diminish the reduction of emissions during operation that HPT is expected to have. Besides that, the transport market of APT, HSR and HPT has also been studied, also taking the impact of the design of the three systems on competitiveness into consideration. Mainly comparing the performance of these modes on cost, travel time, emission, capacity and operations.

The trade-offs and mode choice of travellers for long-distance travel have also been studied. However, no studies were found taking APT, HSR and HPT into consideration together. DCM has been applied to study the role of HSR in the substitution of short-haul flights from a traveller's perspective. The focus was merely on the importance of the different aspects of a trip and several researchers made a distinction between travellers' preferences for business and leisure trips. Also, the willingness to use HPT has been studied by some.

This thesis will apply DCM to analyse the impact of different system designs of HPT on traveller's mode-choice and preferences in the transport market of APT, HSR and HPT, in order to gain insights into the potential of OD-substitution of short-haul flights by HSR and HPT. The aim of this thesis is to analyse the future transport market for long-distance travel within Europe at AAS when considering APT, HSR and HPT, from a traveller's perspective, for different design scenarios of HPT, taking different stakeholder coalitions needed for those design scenarios into account as well. Mode choice and the trade-offs between APT, HSR and APT for long-distance travel can be assessed and the potential role of HSR and HPT in short-haul flights substitution at AAS becomes clear.

2.2 Literature review information provision in the introduction of SP experiments (research objective 2)

The information provision in an SP experiment can be done in various ways. The communication medium used to present the information, the information provided in the introduction and the description of the attributes and attribute levels might impact the outcomes of the choice experiment. The researcher has to balance providing the respondents with information on the included alternatives on the one hand but be cautious for the fact that respondents might take the provided information as clues for the desired answers on the other hand. To gain insights into the status-quo in the scientific literature concerning this topic and to identify the knowledge gaps, a literature review was carried out. Paragraph 2.2.1 will focus on the methodology applied for this literature review. The role of the provided information in as SP experiment is discussed in paragraph 2.2.2, followed by paragraph 2.2.3, in which the focus is on the impact of the communication medium used. Paragraph 2.2.4 addresses the identified knowledge gap this thesis seeks to address.

2.2.1 Methodology

This literature review aims to answer the following three questions. Based on the found answers to those questions, the second knowledge gap this thesis seeks to fill is identified. An overview of the applied search strategy and the included articles can be found in *Appendix B*. The number between brackets behind each question indicates the paragraph in which the question is discussed.

- What has already been studied on the role/impact of the information provided in an SP experiment on found outcomes? (2.2.2)
- What has already been researched in terms of the impact of the provided information on found preferences? (2.2.2)
- What has been studied on the influence of the communication medium used on found preferences and mode-choice? (2.2.3)

2.2.2 Influence of provided information

According to Ben-Akiva, McFadden & Train (2019), DCM can predict the market demand of alternatives relatively well when people are asked to choose among a small number of familiar alternatives, that are realistic and that are fully described. However, when alternatives are unfamiliar for respondents or are incompletely described, the reliability of the stated preferences decreases considerably (Ben-Akiva et al., 2019). When respondents are unfamiliar with the alternatives included in the choice experiment, wording about attributes or the mentioning of an attribute could be seen as clues on what respondents should feel or are expected to feel about a certain attribute (Ben-Akiva et al., 2019; McFadden, 2017; Sugden, 2005). Ben-Akiva et al. (2019) also state that researchers need to inform respondents about the included alternatives as detailed as possible on the one hand, but need to be careful not to influence respondent's valuation of the attributes on the other hand. Doing both asks for careful wording and trade-offs. Familiarizing respondents with the included alternatives is put forward as important. Providing information in the introduction of the SP experiment, providing tutorials or creating real-life experience are mentioned ways to do so (Ben-Akiva et al., 2019; McFadden, 2017). However, McFadden (2017) also addresses the point that training could manipulate model outcomes, especially when unfamiliar alternatives or attributes are included. The experiment thus needs to be set up in a neutral and non-manipulative way. Making the training of respondents and the introduction of the SP experiment neutral can be a complex matter.

A variety of other studies also looked into the impact of attribute framing, the wording used and provided information on perceptions and attitudes of respondents (de Vries, 2017; Howard & Salkeld, 2009; Kragt & Bennett, 2012; Mazoor et al., 2021; Molin, 2005; Özdemir et al., 2009; Raux et al., 2020; Tortolini et al., 2021; Wu et al., 2019). Kragt & Bennett (2012) studied how descriptions of attribute levels affect choices. Two different comparisons are made in that study, on the one hand comparing market alternatives being stated in absolute levels versus relative levels and on the other hand assessing the impact of the use of positive vs negative contextual descriptions of attribute levels on found results. In the first comparison, no significantly different model estimates were found. But a significant difference in results was found on value estimates when using either positive or negative wording (Kragt & Bennettt, 2012). Molin (2005) also assessed the impact of positive and negative wording on attitudes of respondents in a study on the acceptance and willingness to use hydrogen. He found that coloured information has a direct influence on the found perception of hydrogen and had an indirect influence on the attitudes about and the willingness to use hydrogen. Besides that, Mazoor et al. (2021) state that people are willing to take more risk when negative wording is applied.

2.2.3 Communication medium used

Presenting information in an SP experiment can be done in various ways, using different forms of information and different communication mediums. The most common way of presenting the introduction in an SP experiment is by means of plain text. However, other forms of presenting information are becoming increasingly popular and various studies have been conducted on the influence of other ways of presenting the information on attitudes (Arellana et al., 2020; Hoehn et al., 2010; Patterson et al., 2017; Rossetti & Hurtubia, 2020; Sandorf, 2019). Hoehn et al. (2010) assessed the impact on stated choice outcomes of the format in which ecosystem information is presented to respondents, by including both a text-only format and a tabular format. A significantly smaller variance was found in the choice data based on the tabular format than in the text-only format. The notion that different presentations of the same information could lead to different estimates of preference parameters and to different values of error variances is thus confirmed by this paper (Hoehn et al., 2010). The study by Sandorf (2019) underpins the importance of information provision in discrete choice experiments by including videos. The study assessed the impact of whether or not people watched the provided information video's on how attributes are prioritized in their decisions. He found that respondents who did not watch the videos are more focused on cost-related attributes than on non-cost related attributes.

Furthermore, several studies have been conducted on the influence of using virtual reality in DCM (Arellana et al., 2020; Patterson et al., 2017; Rossetti & Hurtubia, 2020). Rosetti & Hurtubia (2020) studied if there is a difference in ecological validity, the extent to which laboratory-generated results are close enough to real-life settings when comparing images and virtual reality videos. Smaller distortions were found when using virtual reality videos compared to using images only. However, Patterson et al. (2017), who compared text-only with virtual reality presentation, did not find a difference in importance given to the attributes. Coefficients found for attributes that were presented using virtual reality instead of text-only were not found to be of more importance for respondents. Patterson et al. (2017) also state concerns on the fact that the use of images in discrete choice experiments could provide more information than is explicitly included in the experiment. This extra information could be of influence on the choices stated by respondents. However, for non-existing alternatives, this is expected to be less of a problem. Furthermore, a comparison between a text-only format and the use of virtual reality format was also studied by Arellana et al. (2020), focussing on landscape and urban planning. Concluded was that the use of virtual reality improves the understanding respondents have of attributes and complex elements included in the experiment and therefore helps respondents to better evaluate the available options.

Van Langevelde-van Bergen (2018) also looked into the effect of the medium used and of the content provided in the introduction of the SP experiment on found preferences, attitudes and drop-out when studying tradable peak credits. The study showed that the wording used in the introduction can influence the results of the study. However, no significant influence of the used communication medium and the content of the introduction was found by van Langevelde-van Bergen (2018). She recommended testing the impact of the different types of introductions in more studies to see if comparable results are found.

There is a wide range of options to vary the introduction in terms of the communication medium used. More in general in information provision, Baggett(1984) studied how visual and auditory information compared to textual information could cause a better generation of mental models of a situation. The outcome was that the human brain is better at and faster in processing, and thus absorbing, of visual and linguistic information than of written text. Both Orzechowski et al. (2005) and

Dijkstra et al. (1996) studied the application of images in choice tasks. They found the use of images to improve realism, and with this to improve the validity of found results. However, the impact of the use of images on found preferences was not studied.

2.2.4 Knowledge gap 2

The impact of wording, attribute framing, and provided information in SP experiments has been studied in a variety of studies and was found to potentially have an impact on attitudes and perceptions. The influence of the use of different communication mediums on attitudes and preferences has also been researched. Found results vary, not providing a unanimous answer. However, these studies focus on information provision throughout the choice experiment, mainly on attributes and attribute levels, not merely on the type of information and wording used in the introduction of an SP experiment. The study by van Langevelde-van Bergen (2018) did investigate the impact of specifically the introduction in SP experiments on the found preferences, attitudes and drop-out. However, no significant impact of the communication medium used was found.

Furthermore, the study of Baggett (1984) found that using visual and auditory information instead of textual information helps people in forming a mental image. Orzechowski et al. (2005) and Dijkstra et al. (1996) applied this notion by incorporating images in the choice task. They concluded that the use of images improves the realism and validity of the results. However, the impact of the application of images on found preferences was not studied. To fill this gap, this thesis will vary its introduction, including a text-only version and a version with both text and images of HPT. This thesis strives to investigate the impact of information provided and communication medium used in the introduction on found preferences, attitudes and drop-out. The underlying reason for doing so is to examine the extent to which the choices made by the researcher when setting up the choice experiment, are of impact on found results. By doing so, the validity of the results obtained using an SP experiment can be evaluated.

2.3 Summary

Two literature reviews have been conducted to identify gaps in scientific knowledge. Two knowledge gaps found will be addressed by this thesis.

1. The potential of HSR and HPT together in the substitution of OD trips currently made by means of APT has not yet been researched thoroughly. This thesis strives to contribute to filling this gap in knowledge by applying DCM, generating insights into the trade-offs and mode choice of travellers when choosing between these three modes. The influence of different system designs of HPT and the role and impact of different stakeholder coalitions on those design scenarios of HPT will also be assessed.
2. Using unfamiliar alternatives in SP experiments requires familiarizing respondents with these alternatives. This can be done in various ways and by means of various communication mediums. However, the impact of the chosen wording and the used communication medium in the introduction of the SP experiment on found preferences, attitudes and drop-out has not been researched thoroughly. Furthermore, the human brain was found to be better at absorbing information from images than from written text. Images have been included in choice experiments before, but the impact of images on found preferences has not been studied yet. This thesis seeks to address the impact of the usage of images in the introduction of the SP experiment on found preferences, attitude and drop-out.

Intermezzo: Review of hyperloop technology

The concept of the hyperloop was introduced in 2013 by Elon Musk (Musk, 2013). The vast majority of literature on hyperloop has focused on the different technical aspects and the technical feasibility of hyperloop (Gkoumas & Christou, 2020a, 2020b). The main technical problems have been resolved more or less, yet the issue of the safety of the system still needs further attention (Gkoumas & Christou, 2020a; Hansen, 2020). The societal impacts of the introduction of HPT have also been researched by various studies (Hansen, 2020; Janić, 2019; Leibowicz, 2018a; van Goeverden, Janic, et al., 2018; van Goeverden, Milakis, et al., 2018; Werner et al., 2016). According to Hansen (2020), a challenge that remains concerning HPT is the issue of safety and of perceived safety by users, as transport takes place through a tube at high speed. Also in the field of policies related to HPT, challenges remain (Leibowicz, 2018; Werner et al., 2016). Additionally, the hyperloop is often positioned as a sustainable transport mode, often being compared with the emission levels of HSR and APT. Janic (2019) and van Goeverden & Janic et al. (2018) focused on generating insight into the potential amount of emissions caused by hyperloop. The energy consumption of the operations of the hyperloop is potentially very low. However, this decrease in emissions during operations is said to be almost completely diminished by the emissions related to construction.

According to Hansen (2020), focusing on travel demand, for hyperloop to become competitive with HSR and APT, hyperloop needs to compete with APT in terms of travel time and travel comfort, yet with fewer emissions as a consequence. When only considering hyperloop and its impact on APT, Decker et al. (2017) found that hyperloop is a more suitable mode than APT for current short-haul flights. Also, the argument that HPT would cause almost no sound pollution, especially when comparing to APT and HSR, is often mentioned. However, Goeverden & Milakis et al. (2018) and Janic (2019) questioned the position of the hyperloop, by arguing that the current capacity of hyperloop of only 28[6] passengers in combination with the high investment cost for the entirely new infrastructure, makes HPT an expensive competitor for HSR and APT. In their view, hyperloop is not sufficiently promising unless capacity is at least doubled and would only be applicable beyond a certain journey distance.

The concept of the hyperloop is being developed by various parties all over the world. Also, a European Hyperloop Program is in place, striving to facilitate collaboration among the different European hyperloop companies, to achieve standardization and the reduce R&D costs for the hyperloop companies. In the province of Groningen in the Netherlands a test track will be built. This project is financed by various governmental bodies on both national and European level and by private companies (European Commission, 2018). Nonetheless, HPT is also being criticized by many, said to not be a realistic option.

The argumentation put forward is that due to the high investment cost, HPT will never become economically feasible. Also, the fact is mentioned that the infrastructure of HPT would be very inflexible. For every connection, infrastructure needs to be in place, compared to APT where only airports are needed. Besides that, the challenge of fitting HPT into the landscape is put forward. Not only is a 'not in my backyard'-situation likely to appear, but also finding the space to locate a straight tube is put forward as a large barrier for HPT to become reality. Lastly, it is argued that faster connections do not necessarily lead to a positive impact on society and the economy, but only facilitates more transport movements (van de Weijer, 2020). In this thesis the discussion on whether HPT will become reality or not is not discussed elaborately. The aim of this intermezzo was to show that the researcher is aware of the potential drawbacks of HPT and of the fact that it may be never becomes reality.

[6] A capacity of 28 is the initial capacity suggested by Elon Musk in the Alpha Paper (Musk, 2013). However, the current capacity of HPT is 60 people per pod.

3. Methodology

In this chapter, the focus is on the methodology of DCM. First DCM in general will be discussed in paragraph 3.1. After that paragraph 3.2 will discuss the different types of DCMs, elaborating on their properties, strengths and weaknesses. Paragraph 3.3 will focus on the data collection method that was applied and lastly, the conducted stakeholder analysis will be discussed in more detail.

3.1 Discrete choice modelling

DCM is a statistical method that can be applied to gain insights into the choices and trade-offs people make when choosing between a finite set of alternatives. The alternatives included together form the choice set and each alternative is characterized by different attributes. These attributes can be alternative specific or general for all alternatives included in the choice set. For each attribute, attributes levels are defined. Choices can be predicted for all values within the included attribute range (Ben-Akiva & Bierlaire, 1999). By estimating the choice model, weights given to the different attributes, by the decision-maker can be derived (Chorus & van Cranenburgh, n.d.).

Two main aims for applying DCM can be distinguished. By applying DCM, the decision-making behaviour of a group of respondents can be predicted and, secondly, the relative importance of the included attributes on decision-making can become clear. These insights can be used to explain choice behaviour, allowing to predict market demand for the included alternative. These insights could also be aggregated to the level applicable for government policies (Chorus & van Cranenburgh, n.d.; Koppelman & Bhat, 2006). By combining this, DCM allows for welfare analysis in which policy interventions are given a monetary value while considering choice behaviour (Chorus, 2018; Chorus & van Cranenburgh, n.d.).

How decision-makers evaluate the attributes of the in the choice set included alternatives, is referred to as the decision rules (Koppelman & Bhat, 2006). Two dominant types of decision rules applied in DCM can be distinguished: Random Utility Maximization (RUM) or Random Regret Minimization (RRM). RUM assumes the decision-maker chooses the alternative in the choice set with the highest utility (McFadden, 2000). RRM on the other hand, assumes decision-makers to choose the alternative that minimizes anticipated random regret (Chorus, 2012). RRM is becoming increasingly popular, but RUM models remain the most widely used. Besides that, RRM can only be applied when using generic alternatives, which is not the case in this thesis. Therefore, this thesis will apply RUM choice modelling.

3.1.2 Random Utility Maximization

RUM choice models are based on the decision rule that decision-makers choose the alternative in the choice set with the largest total utility (Ben-Akiva & Bierlaire, 1999). Total utility is composed of systemic utility, which is everything related to observed factors, and unobserved utility, which is randomness in individuals' choices. The mathematical representation of the utility function is given by the following formula (Chorus, 2018):

$$U_i = V_i + \varepsilon_i = \sum_m \beta_m \cdot x_m + \varepsilon_i \tag{4.1}$$

With:

U_i = the utility of alternative i

V_i = the systematic part of utility of alternative i

ε_i = error term or unobserved utility of alternative i
β_m = Taste parameter of attribute m
X_m = Attribute level of attribute m

Taste parameter β_m is to be estimated in the model. The aim is to find the values for β_m that make the data most likely. The estimated value of β_m refers to the importance of an attribute, relative to other observed characteristics, and relative to unobserved factors (Chorus, 2018). Important to note is that even though the systematic utility of an alternative is the highest, this alternative might still not be chosen, indicating that choices can only be predicated up to a certain probability. Only differences in utility matter, since the utility concept is relative and not absolute (Ben-Akiva & Bierlaire, 1999).

3.2 Choice models

A distinction can be made between various types of choice models. In this thesis Mixed multinomial Logit (ML) models will be applied, using multinomial logit (MNL) as a reference. These two models will be discussed in more detail in this section.

3.2.1 Multinomial Logit models

The most widely used type of discrete choice models are MNL models. This is mainly due to the closed form of the function determining the choice probabilities in MNL models, making the choice probabilities are easy to compute (Train, 2009). The choice probabilities can be calculated using the following formula (Chorus, 2018):

(4.2)

$$P_{in} = \frac{e^{V_{in}}}{\sum_{j=1..J} e^{V_{nj}}}$$

With:
P_i = the probability that alternative i is chosen by the decision-maker n
V_{in} = the systematic utility that decision-maker n gives to alternative i
V_{nj} = the sum of the systematic utility of all alternatives in choice set J given by decision-maker n

Besides the fact that MNL models are easy to compute, MNL models are characterised by the fact that the error term of the utility function are independent and identically distributed (i.i.d), following an Extreme Value (EV) Type I distribution across alternatives, across choice situations and across individuals, with a variance of $\pi^2/6$ (Ben-Akiva & Bierlaire, 1999; Chorus, 2018; Train, 2009). The i.i.d property implies that the unobserved utility of one alternative is not related to the unobserved utility of another alternative. Assuming this leads to another property of MNL models, namely the IIA property: Independence from Irrelevant Alternatives, meaning that the choice probability of choosing one alternative over another, does not depend on a third alternative (Ben-Akiva & Bierlaire, 1999; Chorus, 2018; Train, 2009). However, these properties of MNL models also come along with limitations. The IIA property forms a limitation for the practical application of MNL models.

The by the IIA property assumed error term distribution and substation patterns, are not realistic since similarities between alternatives are not taken into account. When introducing a third alternative that is more similar to one of the already existing alternatives, assuming market share will be taken away in an equal amount from both existing alternatives is not realistic. More similar alternatives are more likely to form substitutes. MNL models do not postulate for that which leads to an overestimation of choice probabilities of alternatives that have something in common (Ben-Akiva & Bierlaire, 1999; Train, 2009). The second limitation of MNL models appears when one individual makes multiple choices, leading to correlations between these choices made by the same individual. MNL models can thus not account for panel effects, since correlations among choices made by the same individual over time are ignored. Furthermore, MNL cannot deal properly with alternatives with the same unobserved attributes (Chorus, 2018; Train, 2009). These mentioned limitations of MNL models bias model outcomes and form the main reason for other types of DCM to come into play, namely ML models. The next paragraph will discuss ML models in more detail.

3.2.2 Mixed Logit models

ML models have three main characteristics, enabling this model type to deal with the shortcomings of MNL models. Firstly, ML models can capture nesting effects. In MNL models, if two alternatives have something in common, e.g. train and bus, that causes variation across individuals which is not captured in the deterministic part of utility, their error terms become correlated. Then, the i.i.d error terms assumption and thus the IIA assumption do not hold anymore. To deal with this, ML models add an extra error component to those alternatives that have something in common. This extra error term represents the degree of correlation among common unobserved utilities. By taking this correlation into account, ML models can correctly exhibit the IIA property, resolving an appearing issue of MNL models. If there is suspicion of correlations among common unobserved factors, ML models should always be estimated. When the extra added error component is zero, MNL models should be used since this shows that no correlations in unobserved factors are in place (Chorus, 2018).

Secondly, ML models can capture taste heterogeneity. Tastes vary across people, even though people are relatively similar. This taste heterogeneity needs to be captured to deal with correlations between unobserved utilities of alternatives with similar attributes. MNL models are not able to capture this correlation. ML models on the other hand can, by adding an extra error term that captures the degree of unobserved taste variation for an attribute, e.g. travel time(Chorus, 2018).

Thirdly, ML models can capture panel effects. MNL models assume that the unobserved utilities of evaluated alternatives by the same individual are uncorrelated. This implies that choices made by the same individual are uncorrelated. However, choices are correlated as a result of variation in tastes and preferences across individuals and no variations in tastes and preferences within the same individual. By ignoring the fact that choices made by the same individual are correlated, there is assumed that the data set contains more data than it in reality does. Too much certainty will be assigned to estimated parameters and standard errors of the model will be underestimated. ML models can deal with this problem by changing the unit of observation from one choice made to the complete sequence of choices made by one individual. By doing so, correlations between choices made by the same individual can be captured (Chorus, 2018). Capture this leads to the following probability function for panel ML models:

(4.3)

$$P(i) = \int_{\nu_n,\beta_n} \left(\prod_{t=1}^{T} \left(P_{ni}^{t} \middle| \nu_n, \beta_n \right) \cdot f(\nu_n, \beta_n) \right) d\nu_n d\beta_n$$

However, this probability function, with integral, is open form and therefore requires simulation, leading to longer computational times than MNL (Chorus, 2018). This forms a drawback of ML models compared to MNL models.

3.1.3 Application of DCM in this thesis

In this research an ML model will be applied, with an MNL model as reference to verify using an ML model instead of an MNL model, by analysing whether or not the ML model better fits the data. Furthermore, respondents will be asked to make a sequence of choices. Therefore, panel effects are expected to be present. The ML model allows dealing with these appearing panel effects and postulates for potential correlations among unobserved factors.

3.3 Data collection method

Before a discrete choice model can be estimated, data need to be collected. Two paradigms to collect choice data can be distinguished: Revealed preference (RP) data and stated preference (SP) data. RP data is collected by observing or asking for actual choices made between market alternatives. By doing so insights can be gained into what people actually did, leading to models with high validity. However, using RP data also has several drawbacks. Firstly, non-existing alternatives, such as HPT, cannot be included. Secondly, only information is provided on the chosen alternative, not on what other alternatives were included in the choice set. Thirdly, multicollinearity often appears, making it complicated to estimate the mode reflecting trade-offs. Forth, a lot of respondents are needed, given that every respondent only makes one choice. Also, when data needs to be collected on less frequently appearing situations, trouble might appear. Using SP data resolves most of the problems appearing when using RP data (Molin, 2018).

In SP data, choices are not observed in real life, but choice sets are constructed by the researcher using experimental designs. Accordingly, using SP data allows to include hypothetical alternatives, to include new attributes and to include attribute levels that are located outside the current attribute range. Furthermore, since the choice sets are made by the researcher, any variation that is needed, can be made and also rarely appearing choice situations can be included. Besides that, multiple choices by one individual instead of one can be observed when using SP data. Even a small sample could thus lead to reliable estimates. Another advantage related to the fact that choice sets are constructed by the researcher is that all choice sets are fully known. Lastly, due to the use of experimental designs, no correlations among attributes appear and multicollinearity can be avoided (Kroes & Sheldon, 1994; Molin, 2018; Train, 2009). However, using SP data also has its limitations.

The main drawback is the fact that a hypothetical bias may appear, referring to the fact that people may choose differently in real life than is being stated in the SP experiment. This could be caused by the fact that people do not know what they would choose in the hypothetical situation or are not willing to give their real preferences and instead provide what they see as the expected and correct answer (Molin, 2018; Train, 2009). Besides that, the hypothetical bias could be also be caused by the fact that choices are not felt by respondents when stating their answer. Also, the fact that there is perfect information and attributes are made explicit, even though they are hidden in real life, could have an impact (Molin, 2018). In this thesis, SP data will be used.

3.4 Summary

This chapter touches upon the data collection and data analysis methodologies applicable and used in this thesis. Data collection in this study will be done by an SP experiment. DCM will be applied to analyse this data. A panel ML model will be estimated, with an MNL model as a reference model to justify using the panel ML model.

4. Identification of the uncertainties in the design of HPT

The design of the future transport market for long-distance travel is situated in a complex socio-technical context in which a variety of stakeholders and stakeholder coalitions play an important role. The stakeholder analysis forms an important basis of this thesis, since the different stakeholders and potential stakeholder coalitions impact the design space. Paragraph 4.1 will be focused on the different stakeholders involved in the design. After that, paragraph 4.2 will discuss the main design uncertainties in the system design of HPT that came forward in the stakeholder interviews. Based on that, the main HPT design uncertainties are discussed and the role of different stakeholders in these design uncertainties is assessed. The likelihood of the needed stakeholder coalitions to be formed will be discussed as well. In paragraph 4.3 a summary of the design uncertainties that will be included for further analysis, is given.

4.1 Stakeholder analysis

A wide range of stakeholders, such as AAS, NS, KLM, Hardt Hyperloop and governmental bodies (see *Appendix M*), is involved in the design of HPT and in the future transport market with APT, HSR and HPT for long-distance transport within Europe. Therefore, a stakeholder analysis is carried out. The aim of this stakeholder analysis is to gain insights into the main uncertainties for HPT design, into potential stakeholder coalitions that could impact that design, and into the powers and interests of the different stakeholders. By doing so, it becomes clear how these different stakeholders influence the solution space for the design and how they play a role in different design options. By means of desk research, a list of stakeholders that are involved in this matter was constructed. After which interviews with the most important stakeholders have been carried out. The interviews were based on an interview protocol that was established beforehand. This interview protocol can be found in *Appendix C.* The main takeaways from the different interviews can be found in *Appendix D* until *Appendix L.*

Three main topics were discussed during the stakeholder interviews. Firstly, what aspects of the design are already fixed and, more importantly, what are the main uncertainties for the design of HPT. Based on this, the design options for the HPT system became clear.

Secondly, the different stakeholders and potential stakeholder coalitions that are present or needed for certain design options, were discussed. Also, the likelihood that these needed stakeholder coalitions will be formed was discussed.

Thirdly, a list of attributes that travellers could perceive as important in their mode choice was discussed. The aim of this was to gain insight into what the main stakeholders perceive as important aspects for travellers when choosing between different modes. Beforehand, a literature study was conducted to construct a list of relevant attributes to discuss with the stakeholders. This list was based on other scientific studies applying DCM to assess long-distance transport. This list of attributes can be found at the end of the interview protocol (*Appendix C*).

4.1.1 Stakeholders

A variety of stakeholders has been identified. An overview of the stakeholders, their role, their interests and their objectives can be found in *Appendix M*. Among the different stakeholders, formal relations can be identified. These interrelations have an influence on the impact stakeholders have on the design and on the way in which there should be dealt with these stakeholders. The formal relations among the stakeholders were schematised by means of a formal chart, which can be found in *Appendix N.*

The stakeholders can be divided into six categories: transport facilitators, transport operators, (inter)national governmental bodies, regional & local governmental bodies, representatives of travellers and others. For the transport operators and facilitators, some notes need to be made. For HPT it is important to note that it is not yet known who will own the infrastructure and who will be the operator(s). For now, Hardt Hyperloop is split into an infrastructure owner and an operator. For HSR, NS is assumed to be the operator, even though NS is not by definition the one operating HSR. Other, yet unknown parties could come into play to do so as well. For APT, only KLM is included as an operator. The reason for doing so is the fact that KLM is responsible for 56% of the passenger demand at AAS. When taking KLM related flights, such as flights by Air France and Transavia, into account as well, more than 80% of the flights at AAS are KLM related (Waterval, 2020). KLM is thus responsible for a large share of flights at AAS. However, other operators of APT could also be involved.

4.2 Uncertainties in the HPT system design

In the stakeholder interviews, a variety of views on the multi-modal system for long-distance travel with APT, HPT and HSR came forward, leading to diverse views on how HPT should be designed. Contradicting views by different stakeholder were found on some aspects of the design, while on other aspects aligned views came forward. Four main design uncertainties came forward during the conducted interviews: location of HPT stations, security checks, baggage handling and ticket integration. Based on these design uncertainties, design scenarios will be constructed in Chapter 10. The aim of applying different design scenarios for HPT is to analyse how travellers' preferences and mode choice differ for different designs of HPT. By doing so, the impact of how the system HPT is designed on the degree of substitution of short-haul flights by HSR and HPT and whether or not the travel demand in WLO scenario high can be met is assessed.

In each design uncertainties, various stakeholders are involved and coalitions among those stakeholders are needed. Therefore, for each of the discussed design uncertainties, the stakeholder coalitions and the likelihood of those coalitions to be formed, will be discussed as well. The conducted stakeholder interviews (*Appendix D* until *Appendix L)* and the stakeholder analysis (*Appendix M)* form the basis in doing so.

The locations of the stations of HPT, discussed in paragraph 4.2.1. Whether or not security checks will be introduced in HPT is discussed in paragraph 4.2.2. Baggage handling is discussed in paragraph 4.2.3 and the matter of ticket integration between different modes and throughout the door-to-door journey of passengers is discussed in paragraph 4.2.4.

4.2.1 Locations of the stations of HPT and HSR

For the location of the station of HPT, diverging views of the different stakeholders came forward. The first proposed option is to locate HPT at AAS. The second option is to locate HPT at a new location outside of AAS, within a 15-minute reach from the city.

The first potential location for HPT is AAS, which is in line with the ambition of AAS to become a leading multi-modal hub in Europe. It is also put forward that in order to substitute flights by means of HSR and HPT, these modes need to be present at AAS. AAS is already connected to a more fine-meshed network that connects the airport to the city. No additional infrastructure thus has to be built in order to connect HPT to the rest of the transport system and to deal with an increase of demand related to the introduction of HPT at AAS. However, concerns are raised whether or not enough space would be available at AAS to facilitate APT, HSR and HPT.

In terms of the stakeholder dynamics, AAS is the main facilitator and binding stakeholder when HPT would be located at AAS. In that case, HPT would form direct competition for APT and for HSR in terms of passenger volumes departing from AAS for journeys within Europe. This is in conflict with the ambition of KLM to transport as many passengers as possible by means of APT. The same goes for NS International, or other international transport operators running trains via AAS. These two parties thus could form a bottleneck in realizing this design option. On the other hand, passengers travelling through Europe by means of HPT arriving at AAS could also be potential customers for both KLM and NS for further journeys in the Netherlands (for NS) or for intercontinental transport (KLM). Another option would be for KLM or NS to operate HPT as well, yet this remains very uncertain. However, the interests of KLM and NS will probably not block this design option to locate HPT at AAS and is thus expected to have no impact on the likelihood of realizing this design option.

Also, the Municipality of Haarlemmermeer, the MRA and the Province of Noord-Holland need to be on board to build the HPT station at AAS. The Municipality of Haarlemmermeer, the MRA and the Province of Noord-Holland all want to improve the accessibility of the region/municipality but also want to maintain and increase the liveability of the area. Their role in the design option in which HPT would be located at AAS thus depends largely on the extra space needed and on the effect of that on the surroundings of AAS and on the landscape in which HPT would be located. To tackle this matter, the Municipality of Haarlemmermeer, the MRA and the Province of Noord-Holland need to be involved closely. On the other hand, increasing the accessibility and international connection of the area by introducing HPT at AAS also comes with economic advantages for these two stakeholders. Therefore, it can be expected that the Municipality of Haarlemmermeer, the MRA and the Province of Noord-Holland are willing to join the needed coalition, not impacting the likelihood of this design option being implemented. Lastly, the HPT operator and the HPT facilitator also need to be involved but locating the HPT station at AAS is not expected to be an issue for them.

The second option put forward in terms of the location of HPT stations is a not yet determined location outside of AAS, within a 15-minutes reach from the city centre. In the stakeholder interviews, it is mentioned that one of the selling points of HSR and HPT, distinguishing HSR and HPT from APT, is the fact that HPT and HSR could bring passengers closer to the city centre than APT does. By choosing AAS as the location for HPT, this advantage of HPT is almost nullified. Nonetheless, the station for HPT is also not expected to be located in the city centre due to a lack of available space and the complexity of fitting the HPT infrastructure into the city landscape. Nonetheless, every reduction in travel time to/from the city to the location of departure of HPT, compared to APT could make HPT more attractive. The current train station of Amsterdam Zuid is also put forward as a potential location for HPT but creating a station elsewhere is also taken into consideration. Hardt Hyperloop aims at locating its stations within a 15-minutes reach from the city centre. If current airports cannot facilitate that, a new location for the HPT stations will be constructed.

Various stakeholders are involved in decision-making on the location of the station of HPT outside of AAS. The municipality of Haarlemmermeer, the MRA and the province of Noord-Holland are crucial stakeholders since their permission is needed to construct the HPT station at a new location. Their willingness to cooperate depends on the requested location of the HPT station, on the needed space and on the impact of the HPT station on its surroundings. On the other hand, the station could also economically boost the area, which could form an incentive for the stakeholders to participate. However, the consequences of this design option for its surroundings are larger than when locating the HPT station at AAS, also caused by the fact that this new location also needs to be connected to the rest of the Dutch transport network. This enlarges the impact on the surroundings of this new HPT location even more. More stakeholder resistance can thus be expected when the HPT station would be built at a new location compared to when HPT would be located at AAS. This makes this design option of locating the HPT station at a new location a bit less likely to happen.

Furthermore, ProRail, NS and regional transport operators are important in this design option. These stakeholders are needed to connect the HPT station to the rest of the public transport system, to the nearby cities and to AAS. Since this only benefits their position and the increases the number of passengers handled, no bottleneck is expected. Especially when subsidies from the Dutch Central government or the Ministry of I&W are in place, ProRail, NS and regional operators are expected to benefit from this and will most likely not form a bottleneck. From an HPT perspective, ProRail, NS and regional operators are crucial since the competitive position of HPT would become very weak if connections to the rest of the transport system are poorly organised. KLM is less involved in this option since the competition is now not located at AAS, giving them less influence in the situation.

To conclude, two different options for the design of HPT are taken into consideration, both with different stakeholder dynamics as a consequence. When locating HPT at AAS, NS and KLM are expected to raise objections since HPT forms competition for them, potentially capturing their passenger demand. However, these stakeholders could also benefit from HPT at AAS, given that the HPT passengers could also become customers for KLM and NS for other parts of their journey. The Municipality of Haarlemmermeer, the MRA and the Province of Noord-Holland will be easier to include in the coalition in this design option, given that it can economically boost the area and the impact on the surroundings of AAS of adding HPT to AAS, are quite limited compared to when a new HPT station is constructed.

When locating the HPT station at a new location, stakeholder dynamics become more complex. The impact on the landscape and its surroundings increases substantially when building a new location. This impact is enlarged even further by the fact that new infrastructure also needs to be built, connecting the new HPT location to the rest of the transport system. The municipality of Haarlemmermeer, the MRA and the Province of Noord-Holland are expected to form more of a bottleneck in this design option, making this design option less likely from a stakeholder perspective than when HPT would be located at AAS.

4.2.2. Security checks

The second design uncertainty that came forward during the stakeholder interviews is whether or not security checks will be included in the design of HPT. Currently, security checks are only in place for APT. For HSR this is very rare in Europe. The Eurostar, running between London and Paris, is an exception to that. In the stakeholder interviews, diverging opinions came forward on whether or not security checks will appear in HPT. The design option in which security checks in HPT will be comparable to APT is considered to be unlikely by most stakeholders. Mainly due to the fact that one of the main potential advantages of HPT is that waiting times are short. By introducing elaborate security checks, this advantage will be partly diminished. Also, the fact that the transport of HSR and HPT stays on the ground instead of travelling through the air, makes introducing elaborate security checks less necessary. Therefore, a less elaborate security check for HPT and HSR is considered to be more probable by most experts that were interviewed. Technological development of security checks also plays a role in this, given that in the future security checks might become less time consuming than the current APT system. Moreover, it is mentioned that since HPT is a new modality, safety standards will be set as high as for current APT. This statement assumes that HPT will be more comparable to APT than to HSR. The last option for the security checks of HPT is to have no security checks at all. Some stakeholders perceive that option to be likely since this would make HPT more comparable to the current HSR network. However, others say that at least a 'light' security check will be included in the HPT design.

In terms of stakeholders, the introduction of security checks for HPT will mainly require a coalition to be formed between the HPT operator and the owner of HPT infrastructure. Space needs to be available at the HPT stations to locate the security checks and the rest of the station need to be designed in such a way that security checks can be smoothly integrated into the passenger flows. These two stakeholders are expected to work together closely since they both benefit from handling as many passengers as possible by means of HPT. No substantive bottlenecks for the design are thus expected to occur when it comes to security checks. The Dutch Central Government could play a role here as well since rules and regulations could be put into place forcing security checks to be introduced or setting requirements on how strict security checks should be.

Additionally, due to the current COVID-19 pandemic, health checks become more of a topic and are being considered by NS International. Others are critical on this topic, stating that as soon as COVID-19 is over health checks will disappear as well. However, the potential introduction of health checks will not be unique for HPT but will most likely then be introduced for APT and HSR as well, if at all. Therefore, health checks are disregarded in this thesis.

In conclusion, the type of security checks, it at all, that will be in place for HPT is uncertain. The first option is to have no security checks at all, leading to no additional waiting time for travellers. The second option is a light security check that is not very time-consuming. Due to technological developments, this light security check can still be thorough. The last option for security checks is to make it very elaborate, as it is now the case when travelling by means of APT.

4.2.3. Baggage handling

The way baggage is handled differs considerably between the current APT and HSR system. What the baggage handling will look like for HPT is not yet known and came forward as third design uncertainty during the stakeholder interviews. Having your luggage accessible during the whole trip is seen as an advantage of HSR. Although, the current HSR design also has its disadvantages, mainly for passengers travelling with larger suitcases. For APT, it is put forward that the reason luggage check-in is available, is related to how a plane is designed, but this was not necessarily done with the traveller in mind. Often APT is seen as the norm for how long-distance transport should look like, but this does not necessarily lead to the best system. Whether the baggage handling of HPT will be comparable to either APT or HSR is still unclear. Both options will therefore be taken into consideration.

The main stakeholders involved in baggage handling are both the operators of HPT, due to vehicle design, and the infrastructure manager of HPT, since the layout of the stations is impacted by whether or not room needs to be made for baggage check-in and baggage flows. It is expected that no problems will arise between these two stakeholders, since both have the same goal in mind. The formation of stakeholder coalitions thus does not make one of the design options, baggage check-in or not, more likely to occur from a stakeholder perspective.

4.2.4. Ticket integration

The last design uncertainty that came forward from the stakeholder interviews was ticket integration of tickets for different modes of transport, in order to facilitate ticketing on a door-to-door basis. Ticket integration was often put forward as an important element for making other modes than APT more attractive. In terms of technology needed, most barriers are expected to be resolved in the coming years.

Moreover, the operators of the different parts of the journeys need to cooperate, which goes hand in hand with a complex legal aspect that currently hinders the realisation of integrated ticketing. The legal issues are thus far more complicated than the technical issues. Transport operators only want to carry responsibility for their own part of a traveller's journey and prefer being in charge of selling the tickets for their transport services by themselves. To realize integrated ticketing, a third party facilitating an integrated ticket and carrying responsibility for the entire trips could be put in place. A coalition between both regional operators and national operators, of different countries, would need to be formed and legal responsibility would need to be shifted to a third party. The European Commission could play a role in this, by taking the initiative and by facilitating this. KLM also positions itself as a potential travel integrator that could play an important role in facilitating integrated tickets, but it wants to do this by providing all services itself. The legal matter of carrying responsibility for a trip operated by other parties is thus not resolved. For HPT, providing an integrated ticket is said not to be easier than for HSR. Due to the fact that resolving this issue is mainly a legal matter, that is more important for transfer substitution than for OD-substitution[7], and is not specifically focused on the design of HPT, ticket integration will not be included in more detail in the design of HPT in this thesis.

4.4 Summary

Design uncertainties with respect to the system design of HPT can be identified on three main aspects of the system. In the different design options, different stakeholders are involved, and stakeholder coalitions need to be formed, making some options more likely to occur than others. The impact of the different design options on the traveller's mode choice and preferences will be assessed in chapter 10. These design scenarios will be varied on the following aspects of the system:

1. **Location of the station of HPT**: the stations of HPT could be located at AAS or at a newly created location within a 15-minute reach from the city centre. Locating HPT at AAS is more likely when taking the stakeholder perspective into consideration.
2. **Security checks:** security checks could be in place or not. Also, the type of security, and thus the time it takes, could vary due to technological developments as well. Three design options in terms of security checks are considered: elaborate security checks, security checks light and no security checks at all. Stakeholders are not expected to make one option more likely than the other, even though not having security checks would allow the stations of HPT to be smaller. Also, rules and regulations in terms of security checks play a role in this matter.
3. **Baggage handling**: the possibility of check-in baggage can be integrated into the system of HPT or not. Stakeholders are not expected to make one option more likely than the other, but different vehicle- and station designs would be required for the different design options of baggage handling.

[7] This thesis merely focuses on OD-passengers with both origin and destination within Europe.

5. Survey design

This chapter will discuss the construction of the SP experiment that will be used to collect the data. The choice experiment will consist of the following parts: the introduction, the choice task, perception questions, questions on the socio-demographics of respondents and verification questions with respect to the provided information on HPT. First, the introduction of the SP experiment and the different versions of the introduction that were included, are discussed in paragraph 5.1. Paragraph 5.2 discuss the construction of the choice task, based on the by ChoiceMetrics (2018) proposed steps. Furthermore, questions will be included in the SP experiment aiming at assessing travellers' perceptions towards mode-specific characteristics of APT, HSR and HPT. These questions are discussed in paragraph 5.3. Also, questions on the socio-demographics of respondents will be included. Paragraph 5.4 discusses these questions in more detail. In paragraph 5.5, the data collection method is explained. Moreover, the survey testing to come to the final survey will be discussed in paragraph 5.6. A conceptual diagram of the variables included in the survey and how they are interrelated is provided in paragraph 5.7. In paragraph 5. 8 a summary of the chapter is given.

5.1 The introduction of the choice task

The second research objective of this thesis is to assess if the way in which HPT is introduced in the SP experiment is of influence on preference, attitude and drop-out. The two different versions of the introduction of HPT that were used are discussed first, after which expectations are set regarding this topic.

5.1.1. The introduction of the SP experiment

The introduction of the SP experiment strives to inform respondents on the topic of the research and on the different alternatives that are included, in a neutral, short way by means of simple language. Only information that would have been accessible to respondents in the real-life choice situation should be included. The key challenge for the researcher in writing the introduction of the SP experiment is informing respondents sufficiently and in a neutral way that is not seen as clues for the desired answer on the one hand but keep the introduction short on the other hand. Two different versions of the introduction were made, which were both presented to half of the respondents that entered the survey. This variation in the introduction contributes to achieving research objective 2 and research question 2.

The first version of the introduction only contains a textual explanation of the research topic and of the different alternatives and attributes that are included in the choice experiment. The textual information on the different alternatives is alternated with questions to select the sample and assess past travel behaviour of respondents. For example, the explanation of the APT alternative was followed by the question if people travelled by plane from AAS in the past five years for trips within Europe, which forms the exclusion criterion for respondents to participate in the survey. The reason for alternating informative text with questions is to give respondents less the feeling that they need to read a long text, but that they have already started answering questions. The full text of this first version of the introduction can be found in *Appendix O*.

In the second version of the introduction, no textual changes were made compared to the first version. The difference is that four different images of the HPT alternative are added. One image showed the in-vehicle layout of HPT, the second image showed how the HPT station could look like, the third image presented the layout of the platforms and the fourth images showed the tube of HPT, located in the landscape. In *Appendix P* the second version of the introduction can be found.

Furthermore, verification questions were included, being asked at the end of the survey, striving to assess the extent to which respondents have read the introduction and to check if a difference in the information that is memorized appears between the two groups that received the different versions of the introduction. This is done by means of direct questions, but also by more indirect questions, asking substantive questions. In the direct questions, there is asked to what extent they read the introduction and whether or not respondents feel they have a good understanding of HPT. The indirect questions are on specific HPT characteristics that were mentioned in the introduction.

5.1.2. Expectations regarding the effect of variation in the introduction of HPT

Various expectations were set on the impact of the use of different versions of the introduction of HPT in the SP experiment. In terms of the drop-out rate, it was expected that the drop-out rate would be lower among respondents who received the introduction with both images and text. The use of images makes it easier for respondents to gain understanding of HPT, improves realism and increases the validity of the found results (Dijkstra et al., 1996; Orzechowski et al., 2005).

Besides that, it was expected that respondents that received the introduction with both images and text would have a better understanding of HPT and would experience the explanation on HPT as clearer than respondents that received the text-only introduction. The reason for this expectation is that the use of images makes it easier for people to understand a concept compared to when only a textual explanation is used (Baggett, 1984).

Additionally, it was expected that respondents that received the introduction of HPT with both images and text would see HPT as more to HSR than to APT, given that the station layout and vehicle layout of HPT are more similar to HSR than to APT and these layouts were shown in the images. For respondents that received the text-only introduction, it was expected that they would see HPT as more similar to APT than to HSR.

5.2 Choice task construction

The choice task was constructed based on the guidelines provided by ChoiceMetrics (2018). A distinction between three steps is made. The first step is the model specification, in which the included alternatives and the accompanying attributes are defined. In the second step, the experimental design of the choice task is generated by defining the included attribute level for the different attributes and alternatives. After that, in step three the questionnaire is constructed.

5.2.1 Step 1 – Model specification

The aim of this step is to define the alternatives and the attributes that need to be included for these different alternatives (ChoiceMetrics, 2018). Three different alternatives are included: APT, HSR and HPT. In order to define the attributes to be included in the choice task, first a literature study was conducted. Other studies applying DCM to analyse the competition between APT and HSR are used as a basis in doing so. Their argumentation for including certain attributes and the found results on the importance of the attributes in the trade-offs and mode choice is used as a criterion to include an attribute in this study. Furthermore, the decision on what attributes should be included is based on the three main design uncertainties that were identified based on the stakeholder interviews (Chapter 4).

- **In-vehicle time:** travel time is often put forward as the main determinant of mode choice when choosing between APT and HSR (Behrens & Pels, 2012; Kouwenhoven, 2009; Kroes & Savelberg, 2019; Li & Sheng, 2016; Pagliara et al., 2012; Román et al., 2007). Román et al. (2007) decomposed travel time into in-vehicle time and access and egress time, which also includes time waiting at stations or airports. Also, the time needed to reach the exit of the airport or station is included in that article. By doing so, insights could be generated in how the different aspects of travel time (access and egress time, waiting time, exit time and in-vehicle time) are determining trade-offs and mode-choice. In this thesis, this division between the different time components is also made, since this could provide valuable information on the HPT design this research strives to analyse. The different aspects of travel time will be discussed in more detail below. For the attribute of in-vehicle time, it is expected that longer in-vehicle time has a negative effect on preference for a certain mode, as travelling longer is less favourable.

- **Waiting time:** Román et al. (2007) explicitly included waiting time. In this thesis waiting time was also included as a separate attribute. The reason for doing so is that waiting time is determined by whether or not security and checks are in place and also by the type of security checks that are used, which is one of the identified design uncertainties for HPT. For APT thorough and time-consuming security checks are in place. For HSR on the other hand, in most cases, no security check is currently applied. In order to analyse the impact and importance of including security checks on preference and mode choice, this attribute will be varied for HPT in the choice experiment. It is expected that longer waiting times have a negative effect on the preference for HPT. Waiting time is not varied in the experiment for APT and HSR, since this thesis does not strive to analyse the impact of APT design and HSR design on preferences and mode-choice.

- **Access and egress time:** another component of travel time that was explicitly included by Román et al. (2007), is access and egress time, referring to the time it takes people to get from their home to the station/airport from which their main transport is departing (access time) or the time it takes people from the station/airport at which their main transport arrives at their final destination (egress time). Access time is not included as an attribute since access time can diverse considerably given that it depends on peoples' residential location. In the SP experiment, there is assumed that APT, HSR and HPT all depart from AAS, since the focus is on the substitution of short-haul flights at AAS. Yet, by assessing the impact of additional in-vehicle time, the impact of other departure locations for HPT on preferences and mode choice can still be analysed. The simplification that travel time for travelling to the HPT station, access time, is weighted in a similar way by travellers as travel time for the main transport, underlies this. Egress time on the other hand will be included explicitly as an attribute for all three alternatives. By including egress time, insights can be generated on the extent to which location of arrival, and thus to some extend location of departure, plays a role in the mode choice of travellers. Expected is that the longer the egress time, the less preferred a certain mode would be.

- **Time to exit:** this attribute, again explicitly included by Román et al. (2007), accounts for the time it takes passengers to get from their vehicle/airplane to the exit of the station/airport. This time is determined by the size of that station/airport but also by how baggage handling is organised. In order to limit the complexity of the choice task, the time needed for walking at the airport/station is included in the attribute of waiting time. Even though the way in which baggage handling is organised for HPT is one of the design uncertainties, time to exit is not included in the choice experiment. Baggage handling is included in the choice experiment as its own attribute, which will be discussed more elaborately below.

- **Travel cost:** the attribute of travel cost is included by many (Behrens & Pels, 2012; Dobruszkes et al., 2014; Kouwenhoven, 2009; Kroes & Savelberg, 2019; Li & Sheng, 2016; Pagliara et al., 2012; Román et al., 2007). Travel cost implies the cost for the journey from origin to destination. Travel cost will be included as an attribute in this choice task for all three alternatives. It is expected that higher travel cost has a negative effect on the preference for a mode.

- **Frequency:** Behrens & Pels (2012), Kroes & Savelberg (2019) and Pagliara, Vassallo & Román (2012) also found frequency to be one of the main attributes determining mode choice when applying DCM. Frequency was found to be of importance since it impacts the extent to which people need to schedule their other activities around travelling. Although, Dobruszkes et al. (2014) found frequency to be of less impact when assessing mode choice between HSR and HPT. The frequencies for APT, HSR and HPT diverse considerably and are already relatively fixed. This attribute thus is not a design uncertainty for HPT and is therefore not included as an attribute. The assumption is made that all modes depart whenever travellers would like. Frequency will also be included in the perception questions (see paragraph 5.3).

- **Perceived level of comfort:** the perceived level of comfort was included by Kroes & Savelberg (2019), which consisted of aspects such as ease of booking and paying and time in advance of booking and paying, available travel information on before-hand and during the journey, luggage handling and comfort at stations or airports and in trains or airplanes. Pagliara et al. (2012) also included the possibility of engaging in additional activities during the trip as an aspect that determines the level of comfort and Li & Sheng (2016) also included Wi-Fi accessibility. Nonetheless, the perceived level of comfort will not be included in this choice task, since this is mostly related to vehicle design which is not one of the design interests of this thesis. Comfort and comfort-related aspects will be included in the perception questions (see paragraph 5.3).

- **Perceived level of safety:** the perceived level of safety was included by Li & Sheng (2016). However, APT and HSR are both very safe modes that have been used widely for a long period of time. Also, HPT is expected to be a safe mode, especially by the time a European network is in place, as is assumed in this research. Therefore, the perceived level of safety is not included as an attribute in this choice task but will only be included in the perception questions (see paragraph 5.3).

- **Service reliability:** Pagliara et al. (2012) and Román et al. (2007) both included the attribute of reliability, referring to delays in the departure of the transport service. In the current APT and HSR systems, reliability is a present issue, with frequently appearing delays as a result. For HPT, reliability is expected to be less of an issue due to the high frequencies. Besides that, service reliability is mainly of importance during the execution phase of transport, not during the design phase. Service reliability will only be included in the perception questions but is not explicitly taken into account as an attribute.

- **Baggage handling:** Kroes & Savelberg (2018) mentioned baggage handling as a determinant of the perceived level of comfort. The way in which baggage handling will be organised in HPT is one of the design uncertainties that often came forward during the stakeholder interviews. Therefore, having checked-in baggage will be included explicitly as an attribute in the choice experiment and will be varied for all three alternatives. The reason for also varying this attribute for APT and HSR is the fact that APT has multiple options for baggage handling.

To conclude, the attributes that will be included in the choice task are travel cost, in-vehicle time, waiting time, egress time and baggage handling.

5.2.2 Step 2 – Generation of experimental design

In this step, the experimental design, described as the hypothetical choice situations respondents will face in the stated choice experiment, will be defined (ChoiceMetrics, 2018). First, the different attribute levels that were included for each of the attributes are discussed, after which the experimental design that will be used is discussed in more detail. For most attributes, three attribute levels were included in order to test for non-linearity. For baggage handling, only two attribute levels were included since testing for linearity is not needed for this attribute. The attribute levels are determined based on three destinations/airports in Europe, located around 500 km from AAS: Frankfurt am Main, London Heathrow and Paris Charles de Gaulle. The 500 km range was chosen since the main focus of AAS for short-haul flight substitution over land, is on destinations around the 500 km range (KLM, 2018). These destinations are chosen based on the top 10 destinations from AAS within Europe in terms of passenger volumes, selecting the top 3 locations with a distance around 500 km from AAS from that list. Since the focus is on short-haul flight substitution, air passenger volumes are leading.

5.2.2.1 Attribute levels

For each of the included attributes, attribute levels have to be defined.

- **Travel cost:** travel cost was included as an attribute for all three alternatives and has three attribute levels. For APT the travel costs are defined based on prices for one-way trips on Skyscannner.com, considering booking 2 months before departure. Only direct flights are included. Cost varying between €47 and €171 were found. Furthermore, the cost for egress transport needs to be included as well, leading to an additional travel cost of €25 on average.

  To define HSR ticket prices, Rome2Rio.com was used, also considering one-way journeys, booking 2 months in advance. Ticket prices varying between €34,90 and €108 euro were found. Since HSR often arrives in the city centre, only an additional €5 is added for egress transport.

  According to Hardt Hyperloop, the cost structure of HPT is said to be comparable to HSR. A price of €0,15 per kilometre is used. Ticket prices are calculated based on this price per kilometre and on direct distances to the three cities. Frankfurt is assumed to be 450 kilometres from AAS, London 490 kilometres and Paris 510 kilometres. Consequently, a price range between €67,50 and €76,50 was found. For HPT also an additional €5 is assumed for egress transport. Since the travel cost for APT, HSR and HPT are relatively similar, the included attribute levels are generalized for the three modes. Three attribute levels were included in the choice experiment for travel cost for all three modes with a distance of €75, leading to the following attribute levels: €35 – €110 – €185.

- **In-vehicle time:** in-vehicle time for APT is based on Skyscanner.com, only taking direct flights into considerations. In-vehicle times (hh:mm) varying between 01:05 and 01:20 were found. According to Hardt Hyperloop, the maximum speed of HPT that is still economically feasible is 700 km/h. Although, acceleration and deceleration also need to be taken into consideration. Therefore, in-vehicle time is calculated based on an average speed of 600 km/h and on the direct distances to the three cities (see travel cost). This leads to in-vehicle times varying between 00:45 and 00:51. In order to vary the design in terms of location of departure, a broad attribute range for HPT was included. The assumption that travel time for accessing a station is valued in the same way as in-vehicle time underlies this. Since the found in-vehicle times for APT and HPT are quite similar, in-vehicle times for APT and HPT are generalised. Three attribute levels with 20 minutes distance are included in the choice task. This leads to the following attribute levels to be included for both APT and HPT: 00:45 – 01:05 – 01:25.

  Current in-vehicle times by means of HSR form again a basis in determining the attribute levels. The routes that were chosen already have relatively advanced and fast HSR connection. Again, Rome2Rio.com was used to define the attribute levels and only direct trips were included. In-vehicle times varying between 03:18 and 04:10 were found. The following three attribute levels, with 30 min distance, are included for in-vehicle time for HSR: 03:15 – 03:45 – 04:15. In this attribute ranges also some room for the fact that HSR will continue to develop in the coming years is incorporated. However, fact remains that travelling by means of HSR is more time consuming than travelling by means of APT and potentially HPT, which is the reason for including different attributes levels for HSR than for APT and HPT.

- **Waiting time:** Whether or not, and the extent to which security checks are in place determines waiting time. For APT and HSR waiting time was fixed to respectively 2 hours and 15 minutes. The main reason for fixing the waiting time for APT and HSR was that we were not interested in the design of those aspects for APT and HSR and varying these in the choice task could make the experiment more complex and time-consuming to fill out for respondents. Waiting time for APT was fixed to 2 hours. The reason for including this value is that airlines usually ask people to be present at the airport two hours before the departure of their flight. In the current HSR system, no security checks are in place and walking distances are short. Travellers thus only need to arrive shortly before departure. However, due to the international character of HSR, travellers arrive slightly earlier than they would for a normal national train, in order to make sure they do not miss their international connection.

  For HPT, whether or not, and in what form security checks will be in place forms an uncertainty in the design. Therefore, a relatively wide range of attribute levels for waiting time is included for HPT, taking the Eurostar system in mind as well. In the Eurostar between London and Paris, a light form of security check at the station is in place. Although this security is less strict and less time consuming than for APT, travellers of the Eurostar are asked to be present 45 min to 1 hour in advance (Eurostar, n.d.).This leads to the following attribute levels, with 20 min distance between consecutive levels: 00:15 – 00:35 – 00:55.

- **Egress time:** Egress time will be varied for all alternatives, across three levels. For APT egress time was determined based on journeys from the three airports to the city centre. GoogleMaps was used to do so. Egress times varying between 00:30 and 00:48 were found.

HSR stations are often located either at the city centre or at the airport. If HSR arrives in the city centre, egress times are very short, but when HSR arrives at airports egress time becomes larger as well.

Hardt Hyperloop strives to design a system in which HPT stations are located within a 15-minute reach of the city. Although, the impact of the proximity of HPT station to the city on preferences and mode-choice is yet unknown. Also, the time needed to exit the station or airport is included in egress time, which also contains time to pick up checked-in baggage. Therefore, a wider range of attribute values is included. This attribute was varied across three levels for all three alternatives, which are 25 minutes apart. The included attribute levels are: 00:05 – 00:30 – 0:55.

- Baggage handling: For all three alternatives the way in which baggage handling is organised is varied over two levels. For APT currently two options are in place. The first option is to have checked-in baggage, the second option is to only have hand baggage. For HSR baggage check-in is not an option yet, but maybe introducing checked-in baggage in HSR as well is something often mentioned in the interviews. The way in which baggage handling will be organised for HPT is not yet known and is one of the design uncertainties. Therefore, the attribute of baggage handling will be varied for all three alternatives over two different levels. The two attribute levels included are the following: baggage is check-in during main transport, a small piece of hand baggage is also allowed, and baggage is not check-in.

Based on the identified alternatives, attributes and attribute levels, the choice task will be designed. This is done by means of an experimental design, using the software of Ngene. The used Ngene syntax to do so can be found in *Appendix Q*. Three labelled alternatives with alternative specific attributes were included: air transport, highspeed rail and hyperloop. The reason for using labelled alternatives is that the alternatives have an alternative specific parameter (ChoiceMetrics, 2018). Furthermore, the design that was used is a fractional factorial design. Using an efficient design would have been most preferable, but in order to do so, priors need to be available. Nonetheless, for HPT priors are not available. Therefore, an orthogonal design was applied. An orthogonal design minimizes correlations among attribute levels in the choice set and satisfies the property of attribute level balance, referring to the fact that each attribute level appears an equal number of times for each attribute (ChoiceMetrics, 2018).

Another option would be to use a full factorial design, with as advantage that all possible choice situations, and thus also all possible effect, are included. However, this leads to a very large number of choice sets, making this type of design not practical (ChoiceMetrics, 2018). Therefore, this design was not chosen for this thesis.

The software of Ngene was instructed to generate a fractional factorial design with 36 choice sets. In order to limit the number of choices each respondent is facing in the experiment, blocking is applied. Four blocks, each containing nine alternatives, were created.

5.2.3 Step 3 - Construction of the questionnaire

In this last step, the applied experimental design is translated to actual choice situations that were presented to the respondents. Each row in the experimental design becomes a choice situation. The questionnaire was a digital questionnaire, made by means of the software Qualtrics. An example of a choice situation is given in *Figure1.* After each choice set, the respondent was asked which of the alternatives (APT, HSR of HPT) they would choose for their trip within Europe. The complete survey can be found in *Appendix R.*

	Plane	Highspeed rail	Hyperloop
Travel cost	€185	€35	€110
Time in main transport(uu:mm)	01:05	03:45	01:25
Waiting time (uu:mm)	*02:00*	*00:15*	00:35
Egress time (uu:mm)	00:55	00:30	00:05
Baggage	Baggage is checked-in during main transport	Baggage cannot be checked in	Baggage is checked-in during main transport

Figure 1: Example of a choice situation

5.2.3 Expectations for parameter estimates

Various expectations in terms of parameter estimates and directions of parameters were formulated. All parameter estimates related to travel cost and travel time were expected to have a negative sign, given that longer travel times and higher travel cost are less desirable for passengers. This is not only in line with intuition but also with found results in other studies applying DCM to analyse travel behaviour (Behrens & Pels, 2012; Kroes & Savelberg, 2019; Terpstra & Lijesen, 2015). Besides that, waiting time is expected to have a larger utility contribution than the other time components that are included (Espino & Román, 2020).

For baggage handling, it was expected that travelling with checked-in baggage would have a positive contribution to the utility of all three modes, compared to the situation when having checked-in baggage is not possible (Araghi et al., 2014; Román & Martín, 2014).

5.3 Perception questions

The aim of including the perception questions was to gain insights into the perception of travellers towards the mode-specific characteristics of APT, HSR and HPT, in order to examine how these perceptions are of influence on found preferences. These insights contribute to answering sub-question 4 of this research. Perception questions were asked with respect to APT, HSR and HPT in order to gain full information. Respondents were asked to answer the perception questions on a semantic, 5-point scale. The included questions were based on the specific characteristics of the different modes. Questions were included on the following aspects: comfort, safety, sustainability, comfort to work during the trip, travel experience, feeling of speed, reliability, frequency, sound of the vehicle during the trip, accessibility of stations/airport, information provision during the trip, information provision at the stations and the ease of booking tickets. An overview of the questions and applied scales for these questions can be found in *Appendix R.*

5.3.2. Expectations of the effect of perceptions

When considering the impact of the perceptions towards the different characteristics of the different modes on preferences, environmental impact was expected to be of importance for both HSR and HPT. Mainly due to the increasing awareness of the negative environmental impact of APT and due to the increasing demand for more sustainable alternatives such as HSR and potentially HPT. A quite substantial utility contribution of the perception of trip comfort for both HSR and HPT was expected as well as a positive perception for the possibility to work during the trip. Perceived safety was also expected to be of positive impact for both modes, but is expected to be of smaller impact on the preference for HSR and HPT (Román & Martín, 2014).

Besides that, the perception of frequency was expected to have a substantial contribution to utility, especially for HPT. The frequency of HPT is said to be very high. When frequencies are high, travellers have to think about their departure time in a lesser extent. A positive perception of frequency for HPT was therefore expected, given the proposed high frequency of HPT. For HSR frequencies are lower than for HPT, but still a positive, but less positive than for HPT, perception is expected (Román & Martín, 2014). The perception of travel experience for HPT is also expected to play a role in travellers mode choice. When travelling with HPT, visual images of the surroundings will be available, but no windows are in place. This travel experience is something new and was thus expected to play a role in travellers' preferences.

Seeing HSR as more reliability is expected to have a large utility contribution of HSR, mainly due to the often-occurring complaint about delays in HSR (Román & Martín, 2014). Seeing HPT as more reliability, is expected to have a lower contribution to utility than seeing HSR as equally reliable.

Lastly, the perception of safety was expected to have a substantial contribution to utility for HPT. For HSR this utility contribution is expected to be smaller than for HPT. HSR is expected to be perceived as very safe, given that this mode of transport has been proven to be safe over a long period of time, leading to substantial utility contribution for HSR (Román & Martín, 2014). For HPT on the other hand safety was expected to be perceived as lower than for HPT, given that the concept is new and still needs to be proven safe.

5.4 Socio-demographics

In paragraph 5.4.1 the inclusion of the questions in the survey regarding the socio-demographic characteristics of respondents is discussed. After that, expectations for the effect of these socio-demographics on preferences and mode choice are set in paragraph 5.4.2.

5.4.1 Socio-demographics in the SP experiment

To gain insights into the composition of the sample, questions regarding respondents' socio-demographics were included in the survey. By doing so one can get an indication of whether or not the respondents are representative of the target group of the population, namely aviation passengers (Ben-Akiva, 2018). Furthermore, knowing the socio-demographics of respondents allows for explaining the heterogeneity in preferences among respondents and allows for defining different user groups based on these characteristics. Doing so could improve the model fit (Ben- Akiva & Bierlaire, 1999). This contributes to answering sub-question seven. The socio-demographics that will be included in this survey are gender, age, highest level of completed education, income, work situation, zip code and the of children living at home. The exact questions regarding the socio-demographic characteristic that were included in the survey, can be found in *Appendix R.*

5.4.2 Expectations of the effect of socio-demographics

In terms of socio-demographics, it was expected that people travelling for leisure purposes would have a higher utility of HSR than business travellers (Behrens & Pels, 2012; Román & Martín, 2014). Besides that, it was expected that higher educated people would choose HSR and HPT more often than lower educated people, given that higher educated are more aware of the negative side effects of their travel behaviour and would thus choose the more sustainable alternatives (Bergantino & Madio, 2020). Furthermore, people with a higher income were expected to have a lower utility of HSR (Bergantino & Madio, 2020).

5.5 Data collection

The target group of people for this study are air passengers at AAS. To ensure that respondents are indeed air passengers, the first question of this survey was whether people have travelled by plane in the past 5 years from AAS. Reason for choosing the margin of 5 years is that it due to COVID-19, the past year has not been representative for travelling and it is not necessary for respondents to have very recent travel experiences.

Data collection was done by the company CG Research. Respondents could earn points by filling out the survey. These points could be exchanged for a bol.com voucher or money could be donated to charity. A group of respondents was recruited that is representative of the Dutch population in terms of socio-demographics and have travelled by plane from AAS in the past 5 years.

5.6 Survey testing

Before sending out the survey, the survey was tested among various people. Different age groups, ranging from 25 to 65 were asked to test the survey, and people with diverse backgrounds were asked to test the survey. Both people with knowledge of transport and people with no specialization in transport were included in the test group. Completing the survey took respondents approximately 12 minutes.

Based on the received feedback, several changes were made to the survey. The feedback consisted of the following points: do not provide too detailed information on the different alternatives but only the necessary information, present the information on the different alternatives in bullet points, use short and easy to read sentences, add a more clear introduction/explanation on the choice sets and what is expected of respondents in these questions, and show more clearly which attribute levels in the choice sets change and which one does not change. Also, various textual changes in the introduction and in the questions were made based on the received feedback.

5.7 Conceptual model

A conceptual model of the different elements and questions included in the survey and of how these variables are interrelated is presented in *Figure 2.* The black arrows represent the main effects on utility. The blue lines represent the effects of interactions on the utility of the different alternatives. The yellow line indicates the effect of the socio-demographics, for which an effect is expected, on utility.

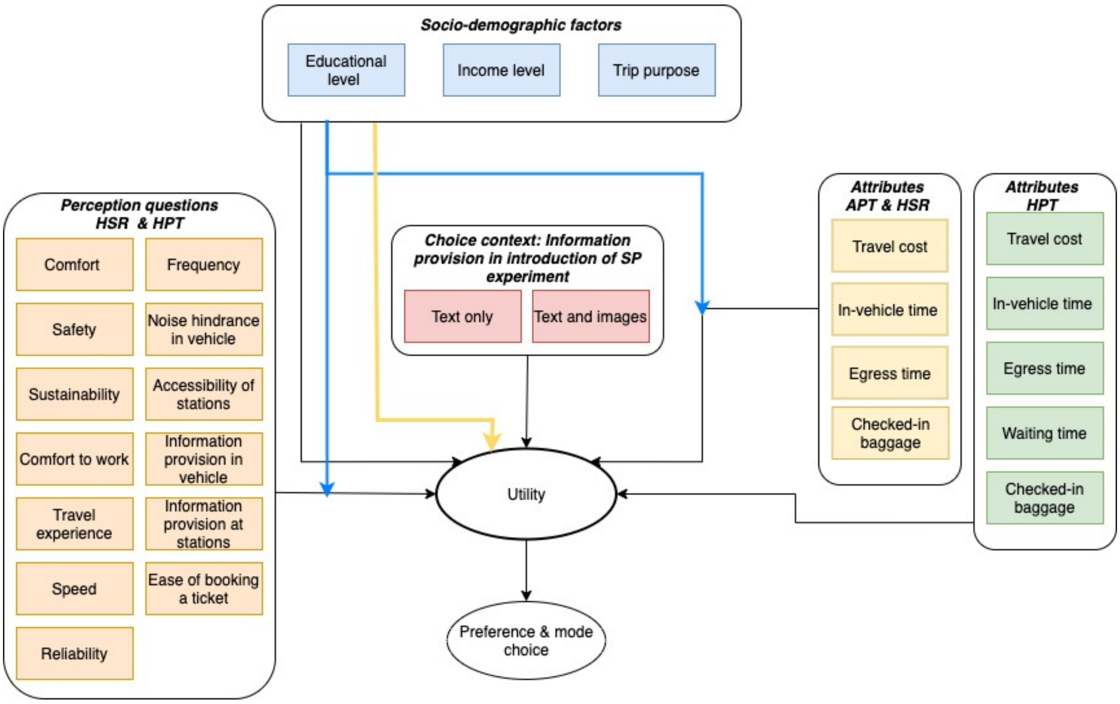

Figure 2: Conceptual diagram

5.8 Summary

The survey consists of 5 sections. A schematic overview of the different parts of the survey is presented in *Figure 3*.

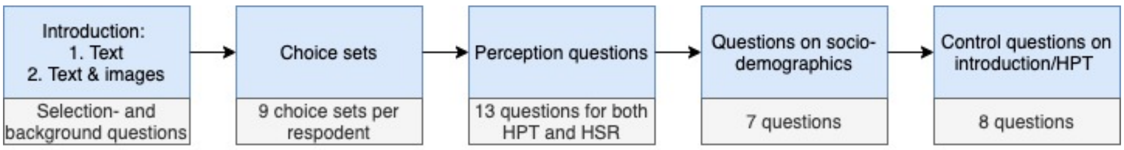

Figure 3: Schematic overview of the survey

Completing the survey is expected to take approximately 12 minutes. In the introduction, the included alternatives and attributes are explained, together with various questions to determine if people meet the selection criterium to participate in this research and to gain insights into their past travel behaviour. Two different versions of the introduction are used, both presented to half of the respondents. One version only contains a textual explanation of HPT, the second version contains both text and images on several aspects of HPT.

In the second section of the survey, nine choice sets are presented to the respondents. Respondents are asked to choose between APT, HSR and HPT in the given situation. The following six attributes varied in the choice task: Travel cost, in-vehicle time, waiting time, egress time and baggage handling. In *Table 1* an overview of the included attribute levels for the different attributes is presented.

Table 1: Overview of attributes and its accompanying attribute levels that were included in the choice experiment

Attribute	Mode	Attribute levels
Travel cost	APT	€35 – €110 – €185.
	HSR	
	HPT	
In-vehicle time (hh:mm)	APT	00:45 – 01:05 – 01:25
	HSR	03:15 – 03:45 – 04:15
	HPT	00:45 – 01:05 – 01:25
Waiting time (hh:mm)	APT	02:00 (fixed)
	HSR	00:15 (fixed)
	HPT	00:15 – 00:35 – 00:55
Egress time (hh:mm)	APT	00:05 – 00:30 – 0:55
	HSR	
	HPT	
Baggage handling	APT	Baggage is not checked-in – Baggage is checked-in
	HSR	
	HPT	

In the third section, respondents are asked to state their perception of several characteristics of APT, HSR and HPT, in order to gain insight into how these perceptions are of influence on the utility of APT, HSR and HPT. For APT, HSR and HPT, 13 perception questions are included.

In the fourth section, seven questions on the socio-demographic factors of respondents were asked. Based on these answers there can be assessed if the group of respondents is representative of the targeted group in the population. These questions also allow explaining the heterogeneity in preferences among respondents and allow for defining different user groups based on that.

In the last section of the survey, eight questions are asked to verify whether or not respondents read the introduction of the survey and to check whether or not a difference appears in the extent to which information about HPT is memorized, comparing the two different introductions that are used. Also, questions assessing respondents understanding of HPT were included in this part of the survey.

6. Data collection and sample characteristics

Data collection took place by means of the survey that was constructed in Chapter 5. Responses to that survey form the input for the DCM. In paragraph 6.1 there is focused on the data gathering procedure and on the obtained response. Moreover, before the collected data can be used to estimate choice models, the data needs to be cleaned. This is also discussed in paragraph 6.1. After that, there is focused on the characteristics of the sample in more detail in paragraph 6.2. In paragraph 6.3 a summary of this chapter is given.

6.1 Data collection

The data collection took place between the 23rd and the 29th of April 2021. In total, 373 respondents opened the survey and 317 respondents completed the survey. The drop-out rate was thus 15,0%. In paragraph 9.2 the drop-out rate is discussed more elaborately.

Before the data could be analysed, the data set needed to be cleaned. In order to do so various criteria were set. Firstly, it was checked if all respondent ID's were unique and only appeared once. Secondly, incomplete responses were excluded. Incomplete responses were mainly caused by respondents not meeting the set selection criterium that one must have travelled by plane in the past five years from AAS. This selection procedure was mainly done by CG Research before respondents entered the survey. However, still three respondents entered the survey that after all were excluded based on this selection criterium. Thirdly, a minimum threshold for completion time was set, in order to make sure that respondents did not just click through the survey without actually reading the questions. The minimum completion time was set to 230 seconds, given that this is the time it takes to just click through the survey without ready the questions. Based on this threshold, eight respondents were excluded. This set threshold is still relatively low but omitting too many respondents based on completion time is not desirable, given that this leads to a loss of information. After this selection procedure, 305 complete responses were remaining and were used for further analysis in this thesis.

Each respondent completed nine choices, leading to 2754 choice observations in total. The blocks were randomly assigned to respondents by the used Qualtrics survey software. Block 1 was completed by 24,5% of the respondents, block 2 by 26,1% of the respondents, block 3 by 23,9% of the respondents and block 4 by 25,5% of the respondents. The fact that every block did not appear an equal number of times, is due to respondents quitting the survey after starting it and due to exclusion of responses during the data clearing process. However, the differences in the number of respondents between four blocks are relatively small and the blocks appear about the same number of times in the data. Therefore, it can be concluded that this distribution among the different choice sets is fine.

6.2 Characteristics of the sample

In order to gain insight into the characteristics and into the composition of the sample, various questions assessing the background characteristics of respondents were included in the survey. The targeted group of respondents were APT passengers who travelled from AAS in the past five years. When giving instructions on the data collection procedure to CG Research, there was asked for a representative sample, which was guaranteed by CG Research. However, whether or not the sample indeed is representative for this specific group of APT passengers cannot be verified, given that no exact distributions on the socio-demographic characteristics of this group are (publicly) available. Furthermore, questions on the past travel behaviour of respondents when making long-distance journeys within Europe were included in the survey as well. In *Table 2* an overview of the sample characteristics and trip characteristics can be found.

Table 2: Characteristics of the sample

Socio-demographics	*Categories*	*Absolute number*	*Percentage*
Gender	Men	145	47.5%
	Women	160	52.5%
	Total	*305*	
Age	0 – 20	6	1.9%
	21 – 40	126	41.3%
	41 – 60	110	36.1%
	61 – 80	62	20.3%
	80 +	1	0.3%
	Total	*305*	
Level of education	Preschool or no education	2	0.7%
	VMBO	24	9.5%
	MBO	85	27.9%
	HAVO of VWO	32	10.5%
	HBO-bachelor of WO-bachelor	126	41.3%%
	WO-masters of PhD	31	10.2%
	Total	*305*	
Income (per year)	<€10.000	24	7.9%
	€10.000 – €20.000	42	13.8%
	€20.000 – €30.000	47	15.4%
	€30.000 – €40.000	49	16.1%
	€40.000 – €50.000	33	10.8%
	€50.000 – €100.000	38	12.5%
	€100.000 – €200.00	6	2.0%
	>€200.000	1	0.3%
	Rather not say	65	21.3%
	Total	*305*	
Employment status	Student	30	9.8%
	Parttime job	20	6.6%
	Fulltime job	171	56.1%
	Retired	48	15.7%
	Jobless	23	4.3%
	Other	13	7.5%
	Total	*305*	
Trip purpose	Business	76	24.9%
	Leisure	229	75.1%
	Total	*305*	
Combining business and leisure[8]	Yes	33	43.4%
	No	43	56.6%
	Total	*76*	
Number of children living at home	No children living at home	200	65.5%

[8] Only taking business travellers into account

	One child living at home	45	14.7%
	Two children living at home	44	14.4%
	Three or more children living at home	16	5.2%
	Total	*305*	
	Travel characteristics		
Travelled with HSR in the past 5 years	Yes	93	30.5%
	No	222	69.5%
Heard of HPT before	Yes, already had a clear image	40	13.1%
	Yes, heard of it before and knew about what it is	91	29.8%
	Yes, heard of it before but did not really know what it is	51	16.7%
	No, never heard of it before	123	40.4%
	Total	*305*	
Usual access station for HSR	Schiphol	30	9.8%
	Amsterdam Central	74	24.3%
	Rotterdam Central	36	11.8%
	Utrecht Central	45	14.8%
	Arnhem	9	3.0%
	Breda	26	8.5%
	No preference	85	27.9%
	Total	*305*	
Travel with check-in baggage when travelling by plane	Always	120	39.3%
	Mostly	99	32.5%
	About as often with as without	49	16.1%
	Almost never	32	10.5%
	Never	5	1.6%
	Total	*305*	
Access mode used to travel to AAS	Car	91	29.8%
	Brought by car	85	27.9%
	Train	113	37.0%
	Other forms of public transport	8	2.6%
	Other	8	2.6%
	Total	*305*	

In each choice situation, respondents were asked to choose between APT, HSR and HPT. APT was chosen in 29,8% choice situation, HSR was chosen in 16,8% of the choice situations and HPT was chosen in 53,3% of the choice situations. HPT was thus chosen more than half of the time. This can potentially be explained by the fact that the average HPT alternative was more attractive than the average alternative for the other two modes or by the fact that resondents felt that HPT was the expected answer. In *Figure 4*, the distribution in choices between APT, HSR and HPT is presented for each choice set.

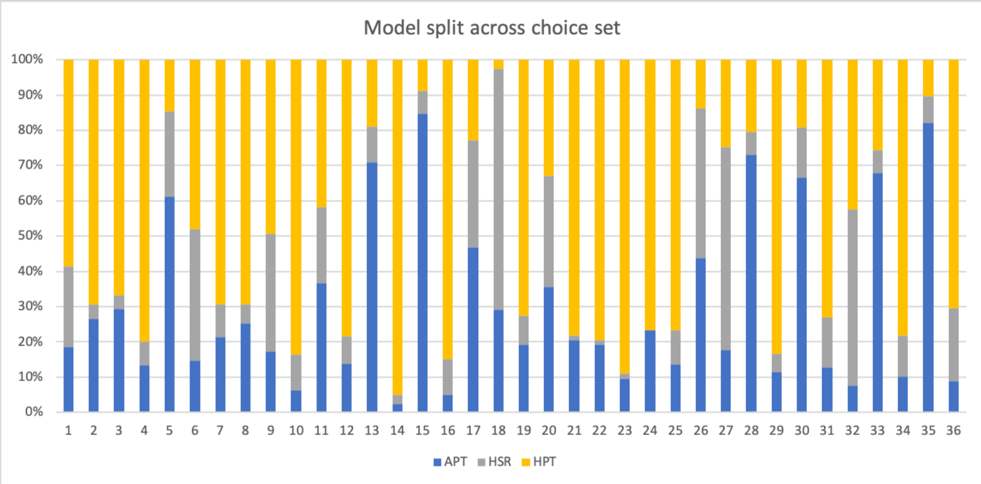

Figure 4: Model split across the 36 choice sets

6.3 Summary

In total 373 respondents opened the survey. Before the collected data could be used for analysis, the had to be cleaned. Respondents with a completion time lower than 230 seconds were excluded. Also, incomplete responses and responses that did not meet the set requirement of having travelled by plane from AAS in the past 5 years, were excluded. In total 305 responses are included in the analysis. These respondents have chosen APT in 29,8% of the choice situations, HSR in 18,6% of the choice situations and in 53,3% of the choice situations HPT was chosen.

7. Methodology

In this chapter, the construction of the discrete choice models is described. First, the data preparation is discussed in paragraph 7.1, after which both an MNL and a panel ML model are constructed in paragraph 7.2. Paragraph 7.3 discusses if using the ML model is justified by comparing the model outcomes and model fit of the MNL model and the panel ML model. A summary of this chapter is given in paragraph 7.4.

7.1 Data preparation

Before choice models could be estimated, the data first needed to be coded. In *Table 3* an overview is provided of the applied coding for the different attributes, socio-demographics and perceptions. For some of the attributes, coding was not needed since these attributes were interval variables.

For in-vehicle time, waiting time and egress time the unit of measurement was changed from hours to minutes. Baggage handling was not measured on an interval scale but a nominal scale. Therefore, dummy coding was applied for this attribute. When applying dummy coding, one of the levels is coded as the reference level, coded with the value zero. The parameter estimates then represent the additional utility of the category that was coded with 1. The constant then expresses the utility of the reference category and no longer represents the constant across all respondents (Molin, 2018). For baggage handling, not having checked-in baggage is coded as the reference category. This variable is therefore labelled as checked-in baggage from now on.

The variables representing the socio-demographic characteristics also had to be coded before they could be added to the utility functions. Both education and income are considered as interval variables even though this is not entirely correct, given that the differences between the categories cannot be assumed to be exactly the same[9]. The lowest education category and the lowest income group were coded with 0. Another note that needs to be made with respect to income is that 21,3% of the respondents answered 'rather not say' when being asked about their yearly income. No information on income is thus available for this group of respondents. In order to still be able to include this group for analysis, there is assumed that this group earns the Dutch modal income. In 2020 this was €36.500 per year (Karthaus, 2021). Respondents were thus assigned to the category of €30.000 to €40.000 yearly income. Trip purpose also had to be dummy coded. The category of travelling for leisure purposes is coded as the reference category, given that this is the most frequently occurring trip purpose in the database.

Table 3: Coding of the included attributes, socio-demographics and trip characteristics

		Attributes	
Variable	**Levels**	**Coding**	**Parameters**
Travel cost APT	€35	35	TC_APT
	€110	110	
	€185	185	
Travel cost HSR	€35	35	TC_HSR
	€110	110	
	€185	185	
Travel cost HPT	€35	35	TC_HPT

[9] The reason for considering these variables as interval variables is that the alternative would be to apply dummy coding, which would lead to many extra variables that have to be estimated in the model. This increase in the number of variables could lead to a decrease in statistical power, implying that the probability of wrongly assuming that a variable is significant, would increase.

	€110	110	
	€185	185	
In-vehicle time APT (hh:mm, coded in minutes)	00:45	45	IVT_APT
	01:05	65	
	01:25	85	
In-vehicle time HSR (hh:mm, coded in minutes)	03:15	195	IVT_HSR
	03:45	225	
	04:15	255	
In-vehicle time HPT (hh:mm, coded in minutes)	00:45	45	IVT_HPT
	01:05	65	
	01:25	85	
Waiting time HPT (hh:mm, coded in minutes)	00:15	15	WT_HPT
	00:35	35	
	00:55	55	
Egress time APT (hh:mm, coded in minutes)	00:05	5	ET_APT
	00:30	30	
	00:55	55	
Egress time HSR (hh:mm, coded in minutes)	00:05	5	ET_HSR
	00:30	30	
	00:55	55	
Egress time HPT (hh:mm, coded in minutes)	00:05	5	ET_HPT
	00:30	30	
	00:55	55	
Checked-in baggage APT			BH_APT
	Baggage is not checked-in	0	
	Baggage is checked-in during main transport	1	
Checked-in baggage HSR			BH_HSR
	Baggage is not checked-in	0	
	Baggage is checked-in during main transport	1	
Checked-in baggage HPT			BH_HPT
	Baggage is not checked-in	0	
	Baggage is checked-in during main transport	1	
	Socio-demographics		
Gender			Gender
	Female	1	
	Male	0	
Age	Real values	18-83	Age
Education	No education or primary school	0	Edu
	VMBO	1	
	MBO	2	
	HAVO or VWO	3	
	HBO-bachelor or WO-bachelor	4	
	WO-master of PhD	5	
Income	Less than €10.000	0	Income
	€10.000 – €20.000	1	
	€20.000 – €30.000	2	
	€30.000 – €40.000	3	
	€40.000 – €50.000	4	
	€50.000 – €60.000	5	
	€60.000 – €70.000	6	
	€70.000 – €80.000	7	
	€80.000 – €90.000	8	

	€90.000 – €100.000	9		
	€100.000 – €200.000	10		
	More than €200.000	11		
Work status			Paid	Retired
	Paid work	0	1	0
	Retired	1	0	1
	Others (student, jobless, other)	2	0	0
Children living at home	No	0	Child	
	Yes (1,2,3 or more)	1		
Business purpose	Business	1	Business	
	Leisure	0		
		Perceptions		
Perceptions	Very low	Range from 1 to 5	Various perceptions	
	Very high			

Various questions assessing the perceptions of respondents towards specific aspects of the three modes were included in the survey. The aim of including these perception questions was to be able to analyse how these perceptions towards mode-specific characteristics of HSR and HPT are of influence on found preferences. Perception questions for APT were also included in the survey in order to gain equal information on all three modes. To avoid multicollinearity among the measured perceptions, first a factor analysis for each of the modes was carried out. By means of factor analysis insights are gained in whether or not variables have enough in common in terms of what is being measured, i.e. enough shared variance, to be combined to one factor (Molin, 2019). Based on the factor analysis, three factors were created for both HSR and HPT.

In the first factor, the perceptions on information provision at the stations, information provided during the trip and way of booking a ticket, are combined. The second factor combines safety and perceived safety and the third factor combines the travel comfort-related perceptions, namely comfort and comfort to work during the trip. For HSR, travel experience is also added to this last factor. For HPT travel experience did not load on the same factor as comfort and comfort to work, indicating that travel experience for HPT did not have enough in common in terms of what is being measured with comfort and comfort to work for HPT. Detailed outcomes of the factor analysis can be found in *Appendix S*. In *Table 4* the average values and standard deviations for each of the perceptions and for the combined factors are presented. The perceptions were measured on a semantic, 5-point scale. In each of the constructed scales, 1 represents a very low score on the perception and 5 a very high score. The perceptions were all coded from 1 to 5.

Table 4: Average values of perceptions for APT, HSR and HPT

Perceptions	*APT* Average	*APT* Standard deviation	*HSR* Average	*HSR* Standard deviation	*HPT* Average	*HPT* Standard deviation
Comfort	3.29	0.915	3.86	0.830	3.77	0.821
Safety	3.95	0.813	4.02	0.729	3.71	0.892
Sustainability	1.99	0.989	3.67	0.860	4.20	0.834
Comfort to work during the trip	2.82	1.070	3.92	0.810	3.64	0.895
Travel experience[10]	3.63	0.915	4.02	0.772	3.40	1.030
Feeling of speed	3.74	1.050	3.73	0.822	4.09	0.826
Reliability	3.62	0.829	3.56	0.878	3.72	0.841
Feeling of safety	3.81	0.807	4.02	0.699	3.71	0.917
Frequency	3.45	0.864	3.45	0.860	3.53	0.861
Sounds of the vehicle during the trip	2.90	1.027	3.33	0.857	3.64	0.866
Accessibility of the stations/airport	3.75	0.9393	3.83	0.889	3.54	0.958
Information provision during the trip	3.76	0.850	3.68	0.859	3.62	0.891
Information provision at the station/airport	3.87	0.788	3.82	0.815	3.73	0.843
Ease of booking a ticket	3.75	0.778	3.83	0.795	3.54	0.847
Factors						
Information provision[11]	-		3.83	0.732	3.74	0.686
Overall safety[12]	-		4.02	0.634	3.71	0.812
Trip comfort[13]	-		3.89	0.632	3.70	0.740

APT is thus seen as the least comfortable mode and HRS as the most comfortable mode. Both APT and HSR are perceived to be very safe and score almost the same on this perception. Interesting to note is that also HPT scores quite high (3.71) on safety. This could indicate that people thus perceive HPT already as safe, even though people have never travelled with it. Besides that, APT is seen as the least sustainable mode (1.99) and HPT as the most sustainable mode (4.20), which is in line with the actual (expected) environmental burdens of the different modes. Moreover, when considering travel experience, it was found that the travel experience for HPT was perceived as the least pleasant (3.40)

[10] Measured on a scale from very unpleasant to very pleasant.
[11] Combined factor of the perceptions of information provision at the station, information provision during the trip and ease of booking a ticket.
[12] Feeling of safety refers to how safe people feel when they travel with a certain mode. Safety indicates how safe the technology of a mode is perceived.
[13] Factor combined from comfort and comfort to work in the vehicle or HPT. For HSR travel experience is also incorporated in the actor.

and the travel experience for HSR was the most pleasant (4.02). However, it should be kept in mind that respondents have no experience yet with travelling by means of HPT, and therefore do not really know how this experience would be.

Furthermore, for feeling of speed[14] it is interesting to note that APT and HSR are seen as very similar in terms of this perception. However, in reality, the speed of a plane is much higher than the speed of a train. Also, the fact that HPT is perceived to be faster than APT should be noted, given that the actual speed of HPT is lower than the speeds of APT. This larger difference in perception could potentially be explained by the fact that travellers' have no experience with how fast HPT would feel during travel.

Moreover, the three modes score very similar in terms of the perceived frequency. This is interesting given that the actual frequencies for APT and HSR can differ quite a lot. No specific information was provided in the frequency of HPT, but the assumption was made that each mode would leave whenever a respondent wants. This could also have played a role in why the found perception values for the three modes are quite similar.

Additionally, in terms of reliability, all three modes are seen as quite similar (APT= 3.62, HSR = 3.56, HPT = 3.72). HSR is seen as the least reliable and HPT as the most reliable. Besides that, the found average perceptions for accessibility of the airport/station stands out, given that the found values are almost the same for all three modes (APT= 3.75, HSR=3,83 and HSR = 3.54). In reality, however, usually airports are more difficult to reach than train stations. The last perception for which found average values stand out is ease of booking a ticket. A common complaint about HSR, which also came forward during the stakeholder interviews (*Appendix D to Appendix L*), is that booking a ticket is not user-friendly compared to APT. However, the found average perceptions do not reflect that.

7.2 Choice model estimation

When people want to travel, they need to choose between the different modes that are available to them. Based on the characteristics of these modes, utility is assigned to each of the alternatives. DCM can be used to assess the utility of each of the alternatives. Two different types of choice models have been estimated. Paragraph 7.2.1 discusses the construction of the MNL model, paragraph 7.2.2 focuses on the construction of the panel ML model.

In both the MNL model and the panel ML model, ASCs were added to the utility functions of both HSR and HPT. APT functions as the reference alternative, given that short-haul flight substitution is under study. The constant for APT is therefore fixed to zero. Both the constant for HSR and for HPT was expected to have a negative sign in the panel ML base model. For HSR this negative inherent preference was expected due to the fact that HSR is currently not very widely used even though the services are quite good, and emissions are relatively low compared to APT. This was also found by Bergantino & Madio (2020). For HPT also a negative sign for the constant is expected given that it is a new mode of transport, people do not have experience with and that has not yet been proven to be safe. A sceptical attitude was therefore expected. These constants and their meaning are discussed in more detail in paragraph 8.3.

[14] Feeling of speeds refers to how fast respondents feel they are travelling when using a certain mode. This is thus not necessarily in line with the actual speed of a mode.

7.2.1 Estimation of the MNL model

Multiple MNL models have been estimated. An MNL model with only generic parameters for all the attributes that were varied in the choice experiment forms the base model. The utility functions used in the MNL base model are presented in *Equation 7.1 to 7.3.*[15]

$$V_{n,APT} = \beta_{TC} * TC_{APT} + \beta_{IVT} * IVT_{APT} + \beta_{ET} * ET_{APT} + \beta_{CB} * CB_{APT} \tag{7.1}$$

$$V_{n,HSR} = ASC_{HSR} + \beta_{TC} * TC_{HSR} + \beta_{IVT} * IVT_{HSR} + \beta_{ET} * ET_{HSR} + \beta_{CB} * CB_{HSR} \tag{7.2}$$

$$V_{n,HPT} = ASC_{HPT} + \beta_{TC} * TC_{HPT} + \beta_{IVT} * IVT_{HPT} + \beta_{WT} * WT + \beta_{ET} * ET_{HPT} + \beta_{CB} * CB_{HPT} \tag{7.3}$$

Before adding other variables to the model, there first was tested whether using alternative specific parameters for each of the attributes led to an improvement in model fit. The reason for testing this is that for example travelling one minute by means of APT is not the same as travelling one minute by means of HPT. In order to determine whether using alternative specific parameters led to a significant improvement in the model fit, a Likelihood Ratio Static test (LRS-test) was performed. This test was used as a guideline for whether or not to include a variable or group of variables in the model.

The alternative specific parameters were added to the model one by one. There was found that adding alternative specific cost parameters to the model did not lead to a significant improvement in model fit compared to the model with only generic parameters (LRS=2.66, df=2, p=0.265). Therefore, a generic cost parameter was used in the MNL models. Adding alternative specific parameters for in-vehicle time to the model did lead to a significant improvement in model fit (LRS=6.67, df=2, p=0.034). The same was found for both egress time (LRS=6.64, df=2, p=0.036) and for having checked-in baggage (LRS=8.8, df =2, p=0.012). Thus, alternative specific parameters were included in the model for in-vehicle time, egress time and checked-in baggage. For travel cost, a generic parameter was included in the MNL model.

From there on, two groups of variables, perceptions and socio-demographics, were added to the utility functions of HSR and HPT. APT functions as the reference alternative, therefore no additional variables are added to the utility function for APT. Only variables for which there is good reason to assume they are of effect on the utility of a certain alternative were added to the model[16]. If the addition of this group of variables led to a significant improvement in model fit, then the variables within that group were added to the model. This is regardless of whether or not individual parameter estimates were significant. Again, an LRS-test was used as a guideline for whether or not to include a group of variables in the model.

Firstly, the perceptions, of which an effect was expected, were added to the utility functions of HSR and HPT. The model fit was significantly improved by the addition of these perceptions (LSR= 156.50, df = 12, p=0.000), justifying their inclusion in the model. Secondly, the socio-demographics were added to the utility functions of HSR and HPT. Educational level, income and trip purpose were added. Again, the inclusion of this group of variables was justified given that it led to a significant improvement in model fit (LSR= 52.47, df = 6, p=0.000). The final utility functions for APT, HSR and HPT are given by *Equation 7.4 to 7.6.*[17] Based on these utility functions the final MNL model was estimated. More detailed

[15] In the equations TC= travel cost, IVT= in-vehicle time, WT= waiting time, ET= Egress time, CB=checked-in baggage.
[16] Set expectations and an underpinning for these expectations can be found in chapter 5 of this thesis.
[17] In the equations TC= travel cost, IVT= in-vehicle time, WT= waiting time, ET= Egress time, CB= Checked-in baggage.

information on the found parameter estimates in the MNL base model, in the two intermediate models and in the final MNL model, can be found in *Table 5*.

$$V_{n,APT} = \beta_{TC} * TC_{APT} + \beta_{IVT_{APT}} * IVT_{APT} + \beta_{ET_{APT}} * ET_{APT} + \beta_{CB_{APT}} * CB_{APT} \tag{7.4}$$

$$\begin{aligned} V_{n,HSR} = {} & ASC_{HSR} + \beta_{TC} * TC_{HSR} + \beta_{IVT_{HSR}} * IVT_{HSR} + \beta_{ET_{HSR}} * ET_{HSR} + \beta_{CB_{HSR}} * CB_{HSR} \\ & + \beta_{comfort_{HSR}} * TripComfort_{HSR} + \beta_{safety_{HSR}} * Safety_{HSR} \\ & + \beta_{frequency_{HSR}} * Frequency_{HSR} + \beta_{environment_{HSR}} * Environment_{HSR} \\ & + \beta_{speed_{HSR}} * Speed_{HSR} + \beta_{reliability_{HSR}} * Reliability_{HSR} \\ & + \beta_{income_{HSR}} * Income + \beta_{education_{HSR}} * Education + \beta_{business_{HSR}} \\ & * Business \end{aligned} \tag{7.5}$$

$$\begin{aligned} V_{n,HPT} = {} & ASC_{HPT} + \beta_{TC} * TC_{HPT} + \beta_{IVT_{HPT}} * IVT_{HPT} + \beta_{WT_{HPT}} * WT_{HPT} + \beta_{ET_{HPT}} * ET_{HPT} \\ & + \beta_{CB_{HPT}} * CB_{HPT} + \beta_{Comfort_{HPT}} * TripComfort_{HPT} + \beta_{experience_{HPT}} \\ & * Experience_{HPT} \\ & + \beta_{Safety_{HPT}} * Safety_{HPT} + \beta_{frequency_{HPT}} * Frequency_{HPT} + \beta_{environment_{HPT}} \\ & * Environment_{HPT} + \beta_{speed_{HPT}} * Speed_{HPT} + \beta_{reliability_{HPT}} * Reliability_{HPT} \\ & + \beta_{income_{HPT}} * Income + \beta_{education_{HPT}} * Education + \beta_{business_{HPT}} * Business \end{aligned} \tag{7.6}$$

7.2.2 Estimation of the panel ML model

The second model that was estimated is a panel ML model. In order to do so, the same steps were taken as were for the construction of the MNL model. The procedure was performed based on 200 Halton draws, given that this led to stable estimates for the σ's of the error terms in the panel ML base model. The additional error terms represent variation across individuals and their choices of the utility of common unobserved factors for e.g. HPT and HSR. These additional error components are estimated on an individual level and allow to capture nesting effects. ML models also capture panel effects, the fact that one individual makes multiple choices. The number of choices is thus not seen as the unit of observation but the sequence of choice made by one individual is leading (Chorus, 2018).

Three error components were added to the first panel ML base model. The first error component was added to both HPT and HSR, called the land error component. The second error component was added to both HPT and APT, called the air error component. The third error component was added to both APT and HSR, called the error component for already existing modes. The found sigma for the air error component was found not to be significant (estimate= 0.292, s.e. = 0.258, t-value = 1.133) and was therefore excluded from the model. In the panel ML base model, generic parameters for the different attributes are estimated and the error components for both the land nest and the nest for existing modes were added to the utility functions. The utility functions for the ML base model can be found in *Equation 7.7 to 7.9.*[18]

$$V_{n,APT} = \beta_{TC} * TC_{APT} + \beta_{IVT} * IVT_{APT} + \beta_{ET} * ET_{APT} + \beta_{CB} * CB_{APT} + \upsilon_{exist} \tag{7.7}$$

[18] In the equations TC= travel cost, IVT= in-vehicle time, WT= waiting time, ET= Egress time, CB= Checked-in baggage.

$$V_{n,HSR} = ASC_{HSR} + \beta_{TC} * TC_{HSR} + \beta_{IVT} * IVT_{HSR} + \beta_{ET} * ET_{HSR} + \beta_{CB} * CB_{HSR} + \upsilon_{land} + \upsilon_{exist} \tag{7.8}$$

$$V_{n,HPT} = ASC_{HPT} + \beta_{TC} * TC_{HPT} + \beta_{IVT} * IVT_{HPT} + \beta_{WT} * WT + \beta_{ET} * ET_{HPT} + \beta_{CB} * CB_{HPT} + \upsilon_{land} \tag{7.9}$$

There was tested whether using alternative specific parameters for the different attributes led to a significant improvement in model fit. First, alternative specific parameters were estimated for travel cost. This did not lead to a significant improvement in model fit compared to the model with only generic parameters (LRS=4.38, df=2, p=0.112). A generic cost parameter was thus used for the model estimation of the panel ML model. After that, alternative specific parameters for in-vehicle time were added to the utility functions. This led to a significant improvement in model fit (LRS = 6.90, df=2, p=0.032). Alternative specific parameters were thus included for in-vehicle time. The same was found for both egress time (LRS=8.44, df=2, p=0.015) and having checked-in baggage (LRS=11.12, df=2, p=0.004). All in all, alternative specific parameters were included for in-vehicle time, egress time and checked-in baggage.

From there on, perceptions were added to the model, with a significant improvement in model fit as a consequence (LRS=106.98, df=12, p=0.000). The perceptions, of which an effect was expected, were thus added to the model. After that, the socio-demographics with an expected effect were added, again leading to a significant improvement in model fit (LRS= 29.40 df= 6, p = 0.000). The final utility functions that resulted from this procedure are given by *Equation 7.10 to 7.12.*[19]

$$V_{n,APT} = \beta_{TC} * TC_{APT} + \beta_{IVT_{APT}} * IVT_{APT} + \beta_{ET_{APT}} * ET_{APT} + \beta_{BH_{APT}} * CB_{APT} + \upsilon_{n,exist} \tag{7.10}$$

$$\begin{aligned} V_{n,HSR} = {} & ASC_{HSR} + \beta_{TC} * TC_{HSR} + \beta_{IVT_{HSR}} * IVT_{HSR} + \beta_{ET_{HSR}} * ET_{HSR} + \beta_{CB_{HSR}} * CB_{HSR} \\ & + \upsilon_{n,exist} + \upsilon_{n,land} + \beta_{comfort_{HSR}} * TripComfort_{HSR} + \beta_{safety_{HSR}} * Safety_{HSR} \\ & + \beta_{frequency_{HSR}} * Frequency_{HSR} + \beta_{environment_{HSR}} * Environment_{HSR} \\ & + \beta_{speed_{HSR}} * Speed_{HSR} + \beta_{reliability_{HSR}} * Reliability_{HSR} \\ & + \beta_{income_{HSR}} * Income + \beta_{education_{HSR}} * Education + \beta_{business_{HPT}} * Business \end{aligned} \tag{7.11}$$

$$\begin{aligned} V_{n,HPT} = {} & ASC_{HPT} + \beta_{TC} * TC_{HPT} + \beta_{IVT_{HPT}} * IVT_{HPT} + \beta_{WT_{HPT}} * WT_{HPT} + \beta_{ET_{HPT}} * ET_{HPT} \\ & + \beta_{CB_{HPT}} * CB_{HPT} + \upsilon_{n,land} + \beta_{Comfort_{HPT}} * TripComfort_{HPT} + \beta_{experience_{HPT}} \\ & * Experience_{HPT} \\ & + \beta_{safety_{HPT}} * Safety_{HPT} + \beta_{frequency_{HPT}} * Frequency_{HPT} + \beta_{environment_{HPT}} \\ & * Environment_{HPT} + \beta_{speed_{HPT}} * Speed_{HPT} + \beta_{reliability_{HPT}} * Reliability_{HPT} \\ & + \beta_{income_{HPT}} * Income + \beta_{education_{HPT}} * Education + \beta_{business_{HPT}} * Business \end{aligned} \tag{7.12}$$

[19] In the equations TC= travel cost, IVT= in-vehicle time, WT= waiting time, ET= Egress time, CB= Checked-in baggage.

7.3 Comparison of the MNL model and the ML panel model

7.3.1. Parameter estimates

Both the final MNL model and the final panel ML model have been estimated based on the final utility functions that were found (*Equitation 7.4* to *Equitation 7.6* for the MNL model, *Equation 7.10* to *Equitation 7.12* for the panel ML model). For running the final panel ML model, there was started using 100 Halton draws. After increasing the number of draws to 400 Halton draws, the sigma estimates became stable. Therefore, 400 Halton draws were used for the final model estimation. The number of draws was not increased further, given that an increase in the number of draws goes hand in hand with an increase in computational times. In *Table 5*, an overview of the parameter estimates in each of the intermediate MNL models and in the final MNL model is presented. In *Table 6* the parameter estimates of both the intermediate models and the final panel ML model can be found. The used Apollo R scripts to come to the presented parameter estimates can be found in *Appendix T* (MNL model) and *Appendix U* (panel ML model).

Table 5: Overview of parameter estimates final MNL model

Parameters	*MNL base model*			*Panel MNL model with alternative specific parameters*			*Panel MNL model with perceptions*			*Final MNL model*		
	Coefficient	Standard error	t-value[20]	Coefficient	Standard error	t-value[21]	Coefficient	Standard error	t-value[22]	Coefficient	Standard error	t-value[23]
						Attributes of the alternatives						
ASC HSR	-0.374	0.260	-1.438*	-1.284	0.619	-2.073	-5.528	0.806	-6.859	-6.482	0.835	-7.767
ASC HPT	1.059	0.109	9.743	0.549	0.303	1.814	-2.536	0.480	-5.280	-3.435	0.505	-6.797
Travel cost	-0.014	0.001	-27.171	-0.014	0.001	-27.032	-0.015	0.001	-27.229	-0.015	0.005	-27.248
In-vehicle time generic	-0.002	0.001	-1.157*	-	-	-	-	-	-	-	-	-
In-vehicle time APT	-	-	-	-0.008	0.003	-2.572	-0.008	0.003	-2.726	-0.009	0.003	-2.857
In-vehicle time HSR	-	-	-	0.0003	0.002	0.146*	0.0002	0.002	0.097*	0.003	0.002	0.106*
In-vehicle time HPT	-	-	-	-0.0000	0.003	-0.002*	-0.0002	0.003	-0.069*	-0.004	0.003	-0.143*
Waiting time HPT	-0.009	0.003	-3.221	-0.009	0.003	-3.396	-0.009	0.002	-3.434	-0.010	0.003	-3.474
Egress time generic	-0.0002	0.001	-0.175*	-	-	-	-	-	-	-	-	-
Egress time APT	-	-	-	-0.004	0.002	-1.781	-0.004	0.002	-1.742	-0.004	0.003	-1.664
Egress time HSR	-	-	-	0.004	0.003	1.475*	0.003	0.003	1.287*	0.003	0.003	1.245*
Egress time HPT	-	-	-	0.001	0.002	0.663*	0.002	0.002	0.732*	0.002	0.002	0.725*
Checked-in baggage generic	0.267	0.0589	4.584	-	-	-	-	-	-	-	-	-

[20] Values provided with * are not significant at a 95% significance level
[21] Values provided with * are not significant at a 95% significance level
[22] Values provided with * are not significant at a 95% significance level
[23] Values provided with * are not significant at a 95% significance level

Checked-in baggage APT	-	-	-	0.488	0.096	5.087	0.496	0.098	5.074	0.492	0.099	4.968
Checked-in baggage HSR	-	-	-	0.069	0.115	0.601*	0.075	0.117	0.639*	0.073	0.118	0.622*
Checked-in baggage HPT	-	-	-	0.228	0.087	2.617	0.233	0.089	2.617	0.225	0.090	2.509
Perceptions towards HSR and HPT												
Trip comfort HSR	-	-	-	-	-	-	0.467	0.111	4.194	0.484	0.115	4.213
Trip comfort HPT	-	-	-	-	-	-	0.377	0.073	5.175	0.382	0.073	5.207
Safety HSR	-	-	-	-	-	-	0.065	0.110	0.589*	0.025	0.112	0.220*
Safety HPT	-	-	-	-	-	-	0.197	0.072	2.755	0.163	0.073	2.245
Frequency HSR	-	-	-	-	-	-	0.107	0.073	1.456*	0.121	0.074	1.641*
Frequency HPT	-	-	-	-	-	-	0.037	0.059	0.620*	0.043	0.059	0.719*
Experience HPT	-	-	-	-	-	-	0.078	0.049	1.700*	0.091	0.049	1.870
Environment HSR	-	-	-	-	-	-	0.268	0.073	3.686	0.252	0.073	3.435
Environment HPT	-	-	-	-	-	-	0.083	0.600	1.383*	0.078	0.061	1.285*
Reliability HSR	-	-	-	-	-	-	0.113	0.071	1.586*	0.152	0.073	2.083
Reliability HPT	-	-	-	-	-	-	0.018	0.062	0.281*	0.046	0.063	0.732*
Speed HSR	-	-	-	-	-	-	0.098	0.072	1.366*	0.137	0.073	1.878
Speed HPT	-	-	-	-	-	-	0.041	0.055	0.731*	0.048	0.056	0.846*
Socio-demographic factors												
Income HSR	-	-	-	-	-	-	-	-	-	-0.016	0.035	-0.460*
Income HPT	-	-	-	-	-	-	-	-	-	0.042	0.028	1.507*
Education HSR	-	-	-	-	-	-	-	-	-	0.296	0.058	5.082
Education HPT	-	-	-	-	-	-	-	-	-	0.247	0.044	5.569
Business HSR	-	-	-	-	-	-	-	-	-	-0.447	0.165	-2.710
Business HPT	-	-	-	-	-	-	-	-	-	-0.404	0.128	-3.161

Table 6: Overview of parameter estimations of the different panel ML models

Parameters	*Panel ML base model*			*Panel ML model with alternative specific parameters*			*Panel ML model with perceptions*			*Final panel ML model*		
	Coefficient	Standard error	t-value[24]	Coefficient	Standard error	t-value[25]	Coefficient	Standard error	t-value[26]	Coefficient	Standard error	t-value[27]
						Attributes of the alternatives						
ASC HSR	-0.447	0.316	-1.414	-1.401	0.416	-3.373	-6.799	0.758	-8.974	-8.219	0.844	-9.735
ASC HPT	1.443	0.145	9.946	0.896	0.308	2.906	-3.001	0.512	-5.863	-4.175	0.578	-7.226
Travel cost	-0.017	0.001	-26.590	-0.017	0.001	-26.692	-0.017	0.001	-27.016	-0.017	0.001	-26.576
In-vehicle time generic	-0.001	0.002	-0.905*	-	-	-	-	-	-	-	-	-
In-vehicle time APT	-	-	-	-0.008	0.004	-2.342	-0.009	0.003	-2.473	-0.009	0.004	-2.547
In-vehicle time HSR	-	-	-	0.001	0.001	0.707*	0.0004	0.000	0.000*	0.0003	0.002	0.181*
In-vehicle time HPT	-	-	-	-0.0001	0.000	-0.733*	-0.0003	0.000	0.000*	-0.0004	0.002	-0.210*
Waiting time HPT	-0.010	0.003	-3.331	-0.010	0.003	-3.530	-0.011	0.003	-3.845	-0.011	0.003	-3.708
Egress time generic	-0.001	0.001	-0.595*	-	-	-	-	-	-	-	-	-
Egress time APT	-	-	-	-0.005	0.003	-1.880	-0.006	0.003	-2.010	-0.005	0.003	-1.739
Egress time HSR	-	-	-	0.004	0.003	1.180*	0.004	0.001	3.187	0.004	0.003	1.221*
Egress time HPT	-	-	-	0.001	0.003	0.416*	0.002	0.002	0.848*	0.002	0.002	0.723*
Checked-in baggage generic	0.334	0.070	4.757	-	-	-	-	-	-	-	-	-

[24] Values provided with * are not significant at a 95% significance level
[25] Values provided with * are not significant at a 95% significance level
[26] Values provided with * are not significant at a 95% significance level
[27] Values provided with * are not significant at a 95% significance level

Checked-in baggage APT	-	-	-	0.618	0.116	5.335	0.619	0.113	5.442	0.617	0.114	5.405
Checked-in baggage HSR	-	-	-	0.087	0.140	0.625*	0.114	0.113	1.013*	0.111	0.100	1.100*
Checked-in baggage HPT	-	-	-	0.281	0.097	2.890	0.268	0.095	2.820	0.267	0.095	2.823
Sigma's for nesting structure												
Sigma land	2.095	0.150	13.948	2.114	0.151	13.975	1.961	0.148	13.272	1.943	0.146	13.307
Sigma existing	0.782	0.119	6.594	0.780	0.118	6.600	0.671	0.117	5.748	0.720	0.115	6.286
Perceptions towards HSR and HPT												
Trip comfort HSR	-	-	-	-	-	-	0.461	0.143	3.296	0.494	0.154	3.202
Trip comfort HPT	-	-	-	-	-	-	0.456	0.081	5.695	0.476	0.087	5.450
Safety HSR	-	-	-	-	-	-	0.172	0.133	1.293*	0.187	0.145	1.294*
Safety HPT	-	-	-	-	-	-	0.144	0.000	0.000*	0.130	0.078	1.670
Frequency HSR	-	-	-	-	-	-	0.068	0.000	0.000*	0.052	0.000	0.000*
Frequency HPT	-	-	-	-	-	-	0.026	0.000	0.000*	0.015	0.000	0.000*
Experience HPT	-	-	-	-	-	-	0.047	0.0289	1.623*	0.057	0.054	1.052*
Environment HSR	-	-	-	-	-	-	0.300	0.099	3.015	0.295	0.101	2.927
Environment HPT	-	-	-	-	-	-	0.185	0.073	2.519	0.172	0.073	2.360
Reliability HSR	-	-	-	-	-	-	0.231	0.081	2.851	0.253	0.102	2.483
Reliability HPT	-	-	-	-	-	-	0.032	0.000	0.000*	0.054	0.065	0.828*
Speed HSR	-	-	-	-	-	-	0.193	0.093	2.069	0.217	0.101	2.145
Speed HPT	-	-	-	-	-	-	0.128	0.067	1.919	0.125	0.066	1.882
Socio-demographic factors												
Income HSR	-	-	-	-	-	-	-	-	-	-0.009	0.000	0.000*
Income HPT	-	-	-	-	-	-	-	-	-	0.073	0.027	2.701
Education HSR	-	-	-	-	-	-	-	-	-	0.415	0.116	3.582
Education HPT	-	-	-	-	-	-	-	-	-	0.312	0.078	4.012
Business HSR	-	-	-	-	-	-	-	-	-	-0.618	0.323	-1.912

Business HPT	-	-	-	-	-	-	-	-	-	-0.475	0.221	-2.150

When comparing the parameter estimates of the final MNL model and the final panel ML model, there can be observed that the absolute values of the found coefficients are larger in the panel ML models than in the MNL models. This can be explained by the additional error components that were added to the panel ML model. The additional error components accommodate for a part of the unobserved heterogeneity in taste. By doing so, the error component eats away from the i.i.d error term variance, but since the i.i.d. error term variance is fixed for normalization reasons, this leads to larger parameter estimates.

Furthermore, in the final MNL model, various parameter estimates were found to be significant that are not found to be significant in the final panel ML model. This is caused by the fact that the MNL model does not take into consideration that multiple choices made by one individual are correlated and thus contain less information. This leads to underestimation of the standard error of the estimated parameters and to an overestimation of the t-values. Due to this, parameter estimates became significant in the MNL model that in fact are insignificant.

7.3.2 Model fit

In *Table 7* a comparison of the model fit of the final MNL model and of the final panel ML model is given. The ρ^2 gives the percentage of initial uncertainty that is explained by the model (Chorus, 2018). It can be noted that the final panel ML model has a larger ρ^2 in comparison to the final MNL model. The MNL model thus explains away 28.40% of the initial uncertainty and the panel ML model 32.89%. Also, the final Log-Likelihood (LL(final)) is improved by the final panel ML model when comparing to the final MNL model.

Table 7: Comparison in model fit between final MNL and final panel ML model

	Final MNL model	Final panel ML model
Number of parameters	32	33
ρ^2	0.2943	0.3398
Adjusted ρ^2	0.2840	0.3289
LL (0)	-3015.691	-3015.691
LL (final)	-2128.234	-1990.849

To determine whether using the panel ML model is justified, there needs to be assessed if using the panel ML model leads to a significant improvement in model fit compared to the MNL model. This is done by means of an LRS test since the two models have the same parameters. The LRS test led to the following results: LRS = 274.76, df= 2, p=0.000. The final panel ML model thus leads to a significantly better model fit than the final MNL model. Using the final panel ML model is thus justified and will therefore be used from now on.

7.4 Summary

Before discrete choice models could be estimated, the data had to be coded. For travel cost, no coding was applied. For in-vehicle time, egress time and waiting time the unit of measurement was changed from hours to minutes. Having checked-in baggage or not was dummy coded, with the having no checked-in baggage as the reference category. Both yearly income and educational level were assumed to be interval variables. Trip purpose was also dummy coded, with travelling for leisure purpose as the reference category.

Also, a factor analysis was carried out, assessing if the measured perceptions could be combined into one factor due to high shared variance among these perceptions. Based on that, three combined factors were created for both HSR and HPT: trip comfort, overall safety and information provision. After that, both an MNL model and a panel ML model were estimated. For both models, first, a base model was defined, only including generic parameters for the attributes that were varied in the choice experiment. In the ML model, two error components were included in the base model as well. One error component was added to the utility functions of APT and HSR, the error component for existing modes, and one was added to the utility functions of HSR and HTP, the land error component. An additional error component for both APT and HPT, the air error component, was also tested. However, the sigma of this error component was found not to be significant. The air error component was therefore excluded from the model.

First, there was assessed whether using alternative specific parameters led to a significant improvement in model fit. This was tested by means of the LRS test. In both the MNL model and the panel ML, using alternative specific cost parameters did not lead to a significant improvement in model fit. Therefore, generic cost parameters were included in both models. For in-vehicle time, egress time and checked-in baggage, using alternative specific parameters on the other hand did lead to a significant improvement in model fit. Therefore, alternative specific parameters were included in both the MNL model and the panel ML model for these attributes.

After that, groups of variables were added one by one to the utility functions. If the addition of a group of variables led to significant improvement in model fit, again tested by means of the LRS test, the group of variables was indeed added to the model. First, the perceptions were added to the model, again leading to a significant improvement in model fit in both the MNL model and panel ML model. Secondly, the socio-demographics with an expected effect were added to the model, again significantly improving the model fit in both models.

Furthermore, there was assessed whether using the panel ML model was justified, by assessing if the difference in model fit between the MNL model and the panel ML model was significant. An LRS test was used to assess this. There was found that the panel ML model indeed is the better fitting model. The panel ML model will thus be used from now on.

8. Results research objective 1

In this chapter, the results of the panel ML model are discussed in more detail. In paragraph 8.1 the utility contributions of the attributes, perceptions and socio-demographics are visualised. The impact of the different attributes that were varied in the choice experiment on mode choice is discussed in paragraph 8.2, followed by the interpretation of the constants that have been estimated in the model, in paragraph 8.3. Additionally, the utility contributions of the included perceptions for HSR and HPT are discussed. These can be found in paragraph 8.4. In paragraph 8.5 it is assessed whether heterogeneous groups of respondents can be identified, based on the socio-demographic factors. The question whether HPT is seen as more similar to APT or to HSR is discussed in paragraph 8.6. In paragraph 8.7 a summary of the chapter can be found.

8.1 Utility contributions of different model aspects

In the choice experiment, the different alternatives, APT, HSR and HPT, were varied in terms of different attributes, over different attribute levels. Based on the choices made between the different alternatives in the different choice set by the respondents, a DCM was estimated. This led to parameter estimates for each of the attributes that were varied in the choice experiment. These parameter estimates reflect the weight of the attribute in calculating the systemic part of the utility of a certain alternative.

In *Figure 5,* the utility contributions of the different attributes, perceptions and socio-demographics are visualized. In each of the graphs, APT is indicated by the blue line, HSR by the grey line and HPT by the yellow line. Utility contribution is on the y-axes and varies from 0.9 to -0.9 for the attributes. For the socio-demographics, the utility on the y-axes vary from 2.5 to -2.5 and for the perceptions, the utility on the y-axes varies from 0 to 3.5. The x-axes represent the levels of the attributes of the perceptions or the categories of the socio-demographics as were varies in the choice experiment.

Figure 5: Visualisation of the utility contribution of the different parameters that are included in the model

8.2 The impact of the different attributes on mode choice

To gain insight into the extent to which the included attributes determine the preferences of travellers when choosing between APT, HSR and HPT for long-distance travel within Europe, the ranges of utility contribution of the different attributes have been determined. An overview of the utility contributions for the attributes that were varied in the choice experiment is given in *Table 8*.

Table 8: Utility contribution of the attributes

Attribute		Range	Min. utility contribution	Max. utility contribution	Difference between min and max
Travel cost	All	€35 – €185	-0.595	-3.145	-2.550
In-vehicle time (hh:mm)	APT	00:45 – 01:25	-0.405	-0.765	-0.360
	HSR	03:15 – 04:15	0.062	0.077	0.015
	HPT	00:45 – 01:25	-0.018	-0.034	-0.016
Waiting time (hh:mm)	HPT	00:15 – 00:55	-0.165	-0.605	-0.440
Egress time (hh:mm)	APT	00:05 – 00:55	-0.025	-0.275	-0.250
	HSR	00:05 – 00:55	0.015	0.165	0.150
	HPT	00:05 – 00:55	0.010	0.110	0.100
Checked-in baggage	APT	Yes/no (0/1)	0	0.617	0.617
	HSR	Yes/no (0/1)	0	0.111	0.111
	HPT	Yes/no (0/1)	0	0.267	0.267

Travel cost

When considering the utility contributions of the different attributes, travel cost has the largest maximum contribution to utility of all three modes (-3.145). The sign of the utility contribution of travel cost is negative, which is in line with the expectations. Higher travel costs are not desirable and have a negative contribution to the utility of an alternative. Higher travel costs for a mode thus make a transport mode less attractive and were found to be of large importance for travellers when choosing between APT, HSR and HPT for long-distance transport. Keeping ticket prices low is thus of large importance if one wants to make a mode more attractive for long-distance transport in Europe.

In-vehicle time

A negative sign for the utility contribution of in-vehicle time was expected for all three modes since longer in-vehicle times are not preferable. This expectation was met for APT and HPT but was not met for HSR. Also, the large variability among the different modes in terms of the maximum utility contribution of in-vehicle time is striking. For APT the maximum utility contribution of in-vehicle time was found to be quite substantial, negative (-0.765) and significant. Longer travel times thus make APT less attractive for travellers. The maximum utility contribution of in-vehicle time for HPT (-0.034) was found to be small, longer in-vehicle time thus barely leads to a more negative utility of HPT. For HSR a positive and very small maximum utility contribution was found for in-vehicle time (0.077). This is not in line with expectation and is counter-intuitive, given that longer in-vehicle times are not desirable from a travellers' point of view. However, the parameter estimates for in-vehicle time for both HSR and HPT are not statistically significant, and both have a very large standard error compared to the parameter estimate. Therefore, no hard conclusions can be based upon these parameter estimates and their utility contributions.

A potential explanation for the small and insignificant parameter estimate for HPT can be found in the novelty effect, referring to the fact that something new is seen as something better than the already existing alternatives (Koch et al., 2018).[28] HPT is a new mode that people do not have travel experience with and therefore value disproportionally positively. However, this novelty effect will fade away when a mode is operational for a while. It is to be expected is that in-vehicle time for HPT will be valued more negatively over time.

A possible explanation for the insignificant parameter estimates for HSR can potentially be found in the Weber effect, suggesting that e.g. ten minutes of additional in-vehicle time matter less when the total in-vehicle time is longer since it is a smaller part of the total in-vehicle time (Huang et al., 2017). In this thesis the in-vehicle time for HSR is always longer than the in-vehicle times for APT and HPT[29], which could have caused that respondents cared less about an additional increase of in-vehicle time compared to this already high in-vehicle time for HSR compared to the other modes. The insignificant parameter estimate with unexpected sign for HSR could also potentially be caused by the fact that the included range of attribute levels was not large enough for HSR. When the included range of attribute levels is too small, changes in that attribute level do not really impact the choices made by respondents, leading to an insignificant parameter estimate. The small and insignificant parameter estimate for HPT on the other hand cannot be explained by the included attribute ranges, given that the included attribute range for APT and HPT is the same and this attribute range for in-vehicle time led to a significant parameter estimate for APT.

Waiting time

The maximum utility contribution of waiting time for HPT was also found to be quite large and negative (-0.605). Travellers thus value additional waiting time, for example caused by security checks, negatively for HPT which is in line with set expectations. Longer waiting times thus make HPT less attractive for travellers. If one wants to make HPT more attractive, minimizing or shortening waiting time would thus be wise to focus on. Besides that, waiting time is the time component for HPT that has the highest negative utility contribution of all the time components for HPT. However, both in-vehicle time and egress time are not significant.

A possible explanation for this relatively large utility contribution for waiting time for HPT could be that travellers expect short waiting times for ground-bound transport services since this is what they are used to when using already existing ground-bound modes such as HSR. If this expectation is not met and waiting times turn out to be longer, travellers find this worse than when long waiting times would have been expected. Waiting times for APT and HSR were both fixed in the choice experiment, to respectively 2 hours and 15 minutes. The effect of waiting time for HSR is incorporated in the constant for HSR. Paragraph 8.3 will discuss this in more detail.

Egress time

When considering the utility contribution of egress time, two things should be noted. Firstly, the utility contribution of egress time for APT is negative, as was expected, but for HSR and HPT the utility contribution of egress time is positive. If APT is thus located further away from the final destination, this would make APT less attractive. This positive utility contribution of HSR and HPT indicates that longer egress times would lead to an increase in utility, making the modes more attractive, which is

[28] The presence of the novelty effect plays a role in all parameter estimations regarding HPT. This could create a bias in the results of this thesis given that the fact that HPT is new also vanished after a while, potentially leading to different model outcomes.

[29] In-vehicle time for HSR is varied between 03:15 – 03:45 – 04:15 (hh:mm), in-vehicle time for HSR and HPT is varied between 00:45 – 01:05 – 01:25 (hh:mm).

counterintuitive. However, the parameter estimates for egress time for HSR and HPT are not significant given that both have a quite small t-value and their standard errors are about equal to the size as the parameter estimates itself. No hard conclusions can thus be based upon these found utility contributions. The parameter estimate for egress time for APT on the other hand was found to be significant, but its t-value was only slightly larger than the significance threshold. A potential explanation for the small and insignificant parameter estimates could possibly be found in including a too-small attribute range, not creating enough difference to impact choice behaviour. However, one should be very careful when warranting that conclusion, given that the parameter for AP was found the be just above the significance level and the same attribute levels were included for APT, HSR and HPT.

The second aspect that should be noted regarding egress time is that the sizes of the utility contribution for APT again differs substantially from the utility contribution for HSR and HPT. A possible explanation for this could be that people see airports as locations far away from the city, from which travelling to the city centre is a more complex matter that is more time consuming than travelling from an HSR- or HPT station close to the city centre. Also, negative associations based on past travel experiences with APT could have played a role here.

Checked-in baggage

The last attribute that was varied in the choice experiment was having checked-in baggage or not. Utility contributions were found to be positive for all three modes, indicating that travelling with checked-in baggage increases the utility of APT, HSR and HPT for travellers compared to when travelling without checked-in baggage. Having checked-in baggage for all three modes thus makes travelling by means of these modes more attractive from a travellers' perspective, compared to a situation in which baggage cannot be checked in. It was expected that travellers would prefer having check-in baggage over not having checked-in baggage. The found utility contributions and set expectations are thus aligned.

When comparing the utility contribution of having check-in baggage for the three modes, it can be seen that for APT having check-in baggage leads to a substantially larger increase in utility than for HSR or HPT. For APT having the option to have checked-in baggage is thus of larger impact on the attractiveness of that mode, when looking from a user perspective, than for HSR of HPT. A possible explanation for this could be found in the endowment effect (Kahneman & Tversky, 1979; Thaler, 1980). This effect implies that people attach more value to something they consider to own than something they do not own, even if this status of ownership has been assigned only minutes before. People are willing to pay more to maintain the situations in which they own something than they are willing to pay to obtain the same situation if it previously was not theirs (Kahneman & Tversky, 1979; Thaler, 1980). In the case of having checked-in baggage, for APT having checked-in baggage is seen as something they own by travellers, given that in the current APT system baggage check-in is always possible. This leads to a higher willingness to pay to maintain this situation of ownership of checked-in baggage. For HSR and HPT travellers do not consider travelling with checked-in baggage as something they own, since having checked-in baggage is not possible in the current HSR system and people have no experience yet with HPT. Therefore, people value the option to obtain having checked-in baggage in HSR and HPT less. This could explain the lower utility contributions of having checked-in baggage for HSR and HPT, compared to APT.

Another explanation for the found differences in utility contributions for baggage handling could be found in the longer waiting time and the larger number of operational steps that travellers have to go through when travelling by APT, compared to HSR and potentially HPT. APT travellers have to spend more time taking care of their baggage themselves before boarding the vehicle than HSR travellers need to. Lastly, in the survey, a question was incorporated asking respondents whether or not they usually travel with checked-in baggage when travelling by plane. Results show that 219 out of the 305 respondents that completed the survey always or almost always travels with checked-in baggage when using APT. This is in line with the high valuation of having checked-in baggage for APT.

8.3 Alternative specific constants

Not only parameters for the included attributes were estimated in the DCM but also constants for both HSR and HPT were included in the panel ML model. Since APT was chosen as the reference alternative, its constant is fixed to zero. [30] The constants for HSR and HPT thus express the utility difference between e.g. HPT and APT if both alternatives have the exact same utility derived from their attributes. It thus captures all unobserved factors that are associated with a mode but were not varied in the choice experiment and the utility difference, compared to the reference, that is caused by differences in attributes and attribute levels.

In this thesis, not all alternatives were varied on the same attributes and attribute levels. The attribute range for HSR for in-vehicle time varied between 03:15 and 04:15 (hh:mm), while the attribute range for APT and HPT for in-vehicle time varied between 00:45 and 01:25. Moreover, waiting time was fixed for both APT and HSR to respectively 2 hours and 15 minutes, while for HPT waiting time varied between 00:15 and 00:55 (hh:mm).[31]

In the ML base model, the effect of these differences in attribute levels for in-vehicle time and in waiting time is included in the constant. In order to find the inherent preferences of travellers for both HSR and HPT, the constants from the ML base model should be corrected for these differences in attribute levels compared to the reference alternative (APT). This can only be done under the assumption that travellers' value in-vehicle time and waiting time in the same way outside of the included attribute range as was found within the attribute ranges that were included in the choice experiment. By calculating the difference in average attribute level for HSR and HPT compared to the reference (APT), and then multiplying these differences by the found parameter estimates for respectively in-vehicle time and waiting time, the impact of the differences in attributes and attribute levels on the constant becomes clear. By then subtracting these values from the ASCs that were found in the ML base model, the inherent preferences for HSR and HPT can be found. Both the constants that were found in the ML base model and the found inherent preferences are presented in *Table 9.* The reason for using the ML base model is that including any background characteristics, such a socio-demographics or perceptions, are of influence on the magnitude of the constant. Only when variables with a mean equal to zero, the constant is not influenced.

Table 9: Overview of estimated constants for HSR and HPT in the panel ML base model and the found inherent preferences

Constant	ML base model[32]	Inherent preference (based on ML base model)
ASC HSR	-0.447	-1.337
ASC HPT	1.443	0.593

[30] Recall: The reason for choosing APT as the reference is that this study is looking into the role of HSR and HPT in the substitution of short-haul flights.

[31] In Chapter 5, the line of reasoning behind the included attribute ranges was discussed in more detail.

[32] The constants for the ML base model are interpreted since adding alternative specific parameters, perceptions or socio-demographics are of influence on the value of the constant, leading to a less pure effect of the inherent preferences.

As can be seen in *Table 9*, an inherent preference for HSR of -1.337 and for HPT of 0.593 was found. For HSR there thus is a negative base utility related to unobserved factors, while for HPT this inherent preference was found to be positive. The direction of the inherent preference for HSR in the base model is in line with set expectation, while for HPT expectation is not met. People thus turn out to see HPT more positively than was expected, in terms of unobserved factors. This could possibly be explained by the novelty effect, as was discussed in paragraph 8.2. Also, the positive and enthusiastic comments about HPT that were placed at the end of the survey underpin this. Another potential explanation for this positive inherent preference for HPT could be that respondents felt that HPT was the expected answer, and therefore were pushed towards choosing HPT. Despite the fact that the introduction and the rest of the choice experiment were formulated as neutral as possible. If APT, HSR and HPT would thus be valued exactly the same in terms of observed factors and were varied in terms of the same attributes and attribute levels in the choice experiment, then APT would be chosen over HSR, while HPT would be chosen over APT.

8.4 Influence of the perceptions towards HSR and HPT on utility

Various perception towards mode-specific characteristics for HSR and HPT were included in the choice model. In *Table 10* an overview is given of the utility contributions of the different perceptions for both HSR and HPT. The perceptions were measured on a semantic, 5-point scale. In each of the constructed scales, 1 represents a very low score on the perception and 5 a very high score.

Table 10: Utility contributions of the different perceptions

Attribute		Parameter estimates	Utility contribution of scale average[33]	Utility difference between minimum and maximum score[34]
Environment	HSR	0.295	0.885	1.180
	HPT	0.172	0.561	0.688
Trip comfort	HSR	0.494	1.482	1.976
	HPT	0.476	1.428	1.904
Frequency	HSR	0.052	0.156	0.208
	HPT	0.015	0.045	0.060
Reliability	HSR	0.253	0.759	1.012
	HPT	0.054	0.162	0.261
Feeling of speed	HSR	0.217	0.651	0.868
	HPT	0.125	0.375	0.500
Experience	HPT	0.057	0.171	0.228
Safety	HSR	0.187	0.561	0.748
	HPT	0.130	0.390	0.520

[33] The perceptions were measures on a scale from 1 to 5. The utility contribution of the scale average is calculated by multiplying the parameter estimate by 3.

[34] The minimum utility contribution indicates the additional utility of someone that scores 1 on a perception. The maximum utility contribution indicated the additional utility of someone that scores 5 in a certain perception.

The parameter estimates for the perceptions indicate how sensitive the utility of a mode is for the extent to which e.g. HPT is seen as environmentally friendly. For each increase of one point on the semantic scale for environment, this thus leads to an increase in utility of HPT of 0.172. The utility of HPT is thus 0.688 utility point higher for a traveller that sees HPT as very environmentally friendly (5), compared to someone that sees HPT as very environmentally unfriendly (1).

When comparing the parameter estimates for HSR and HPT, it should be noted that all the found parameter estimates for the different perceptions are higher for HSR than for HPT. Seeing HSR as very comfortable, as very environmentally friendly, as very reliable, as very frequent and as very safe thus leads to a larger increase in utility than seeing HPT as very comfortable, as very environmentally friendly, as very reliable, and as very frequently does, with a very pleasant experience and as very safe does. An explanation for the smaller utility contributions of the perceptions for HPT could potentially be found in the fact that people have no experience with travelling by means of HPT and thus have less of an idea of how they see HPT in terms of the various perceptions. It also came forward in the comments that were left at the end of the survey that people found it hard to state their perceptions of HPT due to a lack of experience with this mode of transport.

Based on the found utility contributions of the different perceptions for HSR and HPT, it can be observed that that the utility of both modes is most sensitive for the extent to which people see HSR and HPT as comfortable. This is in line with set expectations. Additionally, that the average utility contributions of trip comfort of HSR and HPT are very similar (1.482 for HSR and 1.428 for HPT). Seeing HSR or HPT as a comfortable mode to travel with, thus almost has the same contribution to utility and to how attractive travellers see that mode. This is not very surprising given that a train and a pod look quite similar. Passengers that see HSR or HPT as more comfortable thus find HSR and HPT more attractive to travel with than people that do not see HSR and HPT in that way. For HPT the extent to which the travel experience is perceived to be pleasant (average utility contribution is 0.171) only has a small contribution to the utility of HPT, making travelling by means of HPT more attractive.

Seeing HSR and HPT as more environmentally friendly leads to the second-largest increase in utility when comparing the different perceptions, again meeting set expectations. Travellers that see HSR and HPT thus as more environmentally friendly find HSR and HPT more attractive than travellers that perceive HSR and HPT as less environmentally friendly. However, a difference was found in terms of the average utility contributions of this perception of HSR and HPT (0.885 for HSR and 0.561 for HPT). Seeing HSR as more environmentally friendly thus leads to a larger increase in utility, making HSR more attractive for a traveller, than seeing HPT as equally environmentally friendly does. This is an interesting observation, given that in reality HPT is expected to have a smaller environmental impact than HSR has.

Moreover, seeing HSR and HPT as a more frequently departing mode, only leads to a small increase in utility of both modes (average utility contribution of HSR is 0.156 and the average utility contribution of HPT is 0.045), when considering all included perceptions. Especially for HPT, this is an interesting observation, given that HPT developers are promoting the high frequency of HPT as one of the selling points of HPT. However, this turns out to only be of small impact on the preference for HPT. Set expectations are thus not met.

The extent to which HPT is seen as more reliable only is of small influence on the utility of HPT (average utility contribution is 0.162). For HSR on the other hand, a more positive perception in terms of how reliable HSR is leads to a more substantial increase in utility, making HSR more attractive (average utility contribution is 0.759). The difference in utility, and thus the attractiveness, of HSR between travellers that see HSR as a reliable mode compared to travellers that see HSR as not very reliable, is thus quite substantial. Ensuring that travellers perceive HSR as a reliable mode is thus of more importance for the attractiveness of HSR than it is for HPT to ensure that travellers see HPT as reliable. This is in line with set expectations.

Additionally, travellers that perceive HPT to have a high feeling of speed during the trip have a quite substantially larger utility of HPT than travellers that perceive this feeling of speed to be low (average utility contribution is 0.375). However, the perceived feeling of speed is of less impact on the utility of HPT than on the utility of HSR (average utility contribution is 0.651). This is an interesting observation, given that the actual speed of HPT is substantially higher than the actual speed of HSR. A potential explanation could be found in the lack of travel experience that people have with travelling by means of HPT.

The last perception that was included was safety. In terms of the utility contribution of perceived safety, HSR and HPT were found to be relatively comparable (average utility contribution of HSR is 0.561 and average utility contribution of HPT is 0.390). Travellers that see HSR and HPT thus as safer find these modes slightly more attractive than travellers that see HSR and HPT as less safe modes. However, seeing HSR as safer leads to a slightly larger increase in utility of HSR than seeing HPT are safer would lead to an increase of the utility of HPT. Seeing HSR as safer is thus of larger influence on travellers' preferences than it is for HPT. This is surprising since HSR has already been proven to be safe over the past years, while HPT still needs to prove its concept in reality. The set expectation that HSR is expected to be perceived as safer, leading to a higher utility contribution is thus not met.

In conclusion, travellers that see HSR and HPT as more environmentally friendly and more comfortable leads find HSR and HPT more attractive. HSR and HPT are seen as being relatively similar in terms of these characteristics. Whether HSR and HPT are seen as frequently departing modes, is only of small impact on preferences. This is an interesting outcome given that the high frequency for HPT is put forward as one of the unique selling points of HPT. Besides that, the extent to which travellers perceive HSR to be reliable has a quite substantial impact on the attractiveness of HSR, while for HPT reliability only has a very small impact on travellers' preferences. Lastly, perceiving a higher feeling of speed and a higher level of safety are both only of small influence on the attractiveness of HSR and HPT.

8.5 Variation in preferences and mode choice for different groups of people

The variables for travelling for business purpose, educational level and income were also included in the model. In *Table 11* the utility contributions of these three background characteristics are given for both HSR and HPT.

Table 11: Utility contributions socio-demographics

Background characteristics		Range	Min. Utility contribution	Max. Utility contribution	Difference between min and max
Business purpose	HSR	Leisure – Business	0	-0.618	-0.618
	HPT	Leisure – Business		-0.475	-0.475
Income	HSR	Less than €10.000 – more than €200.000	0	-0.099	-0.099
	HPT	Less than €10.000 – more than €200.000	0	0.803	0.803
Educational level	HSR	No education of primary school – WO-master of PhD	0	2.075	2.075
	HPT	No education of primary school – WO-master of PhD	0	1.560	1.560

It was found that travelling for business purposes has a negative effect on the utility of both HSR and HPT, compared to people travelling for leisure purposes. People travelling for business purposes thus find travelling by means of HSR and HPT less attractive than people who travel for leisure purposes. This effect is found to be larger for HSR than for HPT. This negative effect for business travellers on the attractiveness of HSR and HPT can potentially be explained by the fact that travelling by means of APT is seen as the standard mode of transport for international business trips. Frequent flyer programs and accompanying preferential treatments that are in place for APT could also play a role in this. These findings are in line with set expectations for HSR.

In terms of income, it was found that having a higher income has a negative effect on the utility of HSR and has a positive effect on the utility of HPT. However, this negative utility of HSR was not significant and therefore no further conclusions will be based upon this parameter estimate for HSR. The parameter estimate for HPT on the other hand was found to be significant. People with a higher income thus find HPT more attractive than people with a low income.

Furthermore, it was expected that higher educated people would have a preference for HSR and HPT. This expectation was confirmed: higher educated people have a higher positive utility of both HSR and HPT compared to lower educated people. Higher educated people thus find HSR and HPT more attractive than lower educated people. Educational level was found to be of the largest influence on preferences, when comparing the included background characteristics, for both HSR and HPT.

Overall, it can thus be concluded that based on the included socio-demographics, heterogeneous groups can be identified. People travelling for leisure purposes, people with a higher income and people with a higher level of education turn out to find and HSR more attractive than people travelling for business purposes, than people with a lower income and than people with a lower educational level.

8.6 Is HPT seen as more similar to APT or to HSR?

In order to determine if HPT is seen as more similar to APT of to HSR, and thus to what extent HPT could be (party) categorized in the nests of air transport or land transport, additional error components were added to the panel ML base model. To both APT and HPT, υ_{air} was added, and to both HSR and HPT, υ_{land} was added. For both of the error components, σ was estimated in the ML base model, σ_{air} and σ_{land}. The value of σ represents the standard error of the error component, and thus represents the variation across individuals in the unobserved factors that are associated with a e.g. HSR and HPT. A larger σ indicates a higher degree of heterogeneity and a stronger nest. This means that there is a higher degree of competition among alternatives within that nest, compared to alternatives outside the nest. σ is estimated on an individual level.

The value for σ_{air} was not significant, indicating only a small degree of competition between APT and HPT, if at all. Since σ_{air} was not significant, it was excluded from the model. σ_{land} was found to be significant and quite substantial in the panel ML base mode. An overview of the found value for σ_{air} in and for σ_{land} in the ML base model is given in *Table 12.*

Table 12: Sigma estimates

σ	Estimate	Standard error	t-value
σ_{air}	0.292	0.258	1.133
σ_{land}	2.095	0.150	13.948

This large sigma for the land nest means HPT is seen as more similar to HSR than to APT by travellers. HPT is thus mainly in competition with HSR and is expected to take more market share from HSR than from APT. This finding that HPT is seen as more similar to HSR than to HPT by travellers can be verified by looking at the found parameter estimates in the panel ML models. The parameter estimates for HSR and HPT are very similar to each other for in-vehicle time, egress time and having checked-in baggage and differ substantially from the parameter estimates of APT on these attributes. This means that travellers' thus value the various aspects of a trip with HSR or HPT in a similar way and for APT in a different way. This was also confirmed by comparable perceptions of travellers towards some of mode-specific characteristics of HSR and HPT. All in all, HPT is seen as more similar to HSR by travellers and is, therefore, more in competition with HSR than with APT.

8.7 Summary

Based on the parameter estimates, the utility contributions of the different variables were calculated. When considering the different attributes, travel cost was found to have to largest utility contribution for all three modes. Lower ticket prices thus have a positive effect on the attractiveness of a mode from a user perspective. In terms of in-vehicle time, a negative utility contribution was found for APT. However, the found parameter estimates for HSR and HPT are not significant and have large standard errors. No hard conclusions can thus be based upon these parameter estimates. This insignificant parameter estimate for HPT could be caused by the novelty effect. For HSR a possible explanation for the counter-intuitive sign and small parameter estimate can be found in the Weber effect or in having included too small attribute ranges.

Egress time was found to be of significant and quite substantial impact on the utility of APT. If APT is thus located further away from the final destination, this makes APT less attractive. However, for HPT and HSR egress time was found to be positive, which is counter-intuitive, but not significant. No hard conclusions can thus be based upon these parameter estimates.

Waiting time is the time component with the largest contribution to the utility of HPT, for HSR waiting time is included in the constant. Waiting time is caused by e.g. security checks and walking distances at the station or airport. These processes should thus be as less time consuming as possible in order to make HPT more attractive for travellers.

In terms of baggage handling, positive utility contributions were found for all three modes. Providing the option to have checked-in baggage thus makes APT, HSR and HPT more attractive for travellers. The largest utility contribution for having checked-in baggage was found for APT, compared to the other two modes. A possible explanation for this could be found in the endowment effect or in the larger number of process steps a passenger needs to go through when travelling by APT.

Moreover, the inherent preferences for HSR and HPT were studied. It was found that travellers have a negative inherent preference for HSR and a positive inherent preference for HPT. If all attributes and attributes would thus be the same for both alternatives, HPT would be the more attractive mode of transport.

Furthermore, the different perceptions that were added to the model were found to be of positive influence on the utility of HSR and HPT. Seeing HSR and HPT as more environmentally friendly and more comfortable leads to the largest increase in utility of HSR and HPT. HSR and HPT are seen as relatively similar in terms of these characteristics. Whether HSR and HPT are seen as frequently departing modes, is only of small impact on utility. This is an interesting observation given that the high frequency for HPT is put forward as one of the unique selling points of HPT. Besides that, the extent to which travellers perceive HSR to be reliable has a quite substantial impact on the attractiveness of HSR, while for HPT reliability only has a very small impact on utility. Lastly, feeling of speed and safety are both only of small influence on the utility of HSR and HPT. Seeing a mode as safer leads to similar increases in utility, when comparing HSR and HPT, while for feeling of speed a larger difference was found between these two modes.

The utility contributions of the socio-demographics were also analysed in order to assess whether heterogeneous groups can be identified based on these factors. It was found that travelling for business leads to a lower utility of both HSR and HPT than travelling for leisure purposes, that people with a higher income value HPT higher than people with a lower income and that a higher educational level also has a positive utility contribution for HSR and HPT. Leisure travellers, people with a higher income or people with a higher educational level are thus more likely to use HSR and HPT.

Lastly, it was analysed whether HPT is seen as more similar to APT than to HSR. σ_{air} was not significant, σ_{land} on the other hand was significant. HSR and HPT are thus seen as more similar in terms of unobserved factors. HPT is thus more in competition with HSR than with APT.

9. Research objective 2

In this chapter, the focus will be on the second research objective. The aim is to assess the impact of the way in which HPT is introduced in the SP experiment on drop-out, preferences and attitude. First, in paragraph 9.1 the data characteristics with respect to the different versions of the introduction are discussed. After that, the influence of the use of images in the introduction on drop-out is discussed in paragraph 9.2. Paragraph 9.3 focuses on the influence of the use of images in the introduction of the SP experiment on choice behaviour, followed by an analysis of the understanding of HPT for both introduction versions of the introduction in paragraph 9.4. Also, the influence of the different versions of the introduction on the question of whether people see HPT as more similar to APT or to HPT is discussed. This can be found in paragraph 9.5. Paragraph 9.6 provides a summary of this chapter.

9.1 Data characteristic

Two different versions of the introduction were included in the SP experiment. In the first version of the introduction, HPT was explained only by means of text. In the other version of the introduction, both text and images were used. In the Qualtrics software, the survey was programmed in such a way that both versions of the introduction were assigned to an equal number of respondents. However, due to respondents dropping out after starting the survey and due to data cleaning, a different number of completed responses for the two versions of the introduction was found in the final dataset. The different versions of the introduction can be found in *Appendix O* and *Appendix P.* The distribution of respondents among the two versions of the introduction and the exact number of complete responses for both versions of the introduction can be found in *Table 13.*

Table 13: Descriptive statistics of the two versions of the introduction

Version of the introduction	*Number of complete responses*	*Percentage of total responses*
Text only	155	50.8%
Text and images	150	49.2%

The distribution among the two versions of the introduction is almost equal. The text-only introduction was received by slightly more respondents than the introduction with both images and text. However, the difference in the number of respondents is very small and therefore not problematic.

9.2 Influence of the use of images in the introduction on drop-out

Of the 373 people who opened the survey, 56 people did not complete the survey. 19.6% of the respondents, 11 respondents in total, dropped out of the survey before making it to the introduction on HPT. 46.7% of the people that dropped out after reading the HPT introduction, received the text-only introduction and 53.5% received the introduction with both text and images. The drop-out rate was thus slightly higher for people receiving the text and images introduction, but the difference is almost negligible. An overview of the occurrence of both versions of the introductions for different moments of drop-out is given in *Table 14.*

Table 14: Overview of moment of drop-out and version of the introduction

Moment of dropping out	Percentage of total drop-out (absolute number)	Text-only introduction	Text & images introduction
After reading the welcome message	12.5% (7)	-	-
Before reading the introduction of HPT	7.1% (4)	-	-
Before starting the choice sets, after reading whole the introduction	30.4% (17)	41.2% (7)	58.8% (10)
Before answering the perception questions, after the choice sets	41.1% (23)	43.5% (10)	56.5% (13)
Before the questions on socio-demographics, after the perception questions	5.3% (3)	100% (3)	0% (0)
Before/during answering the questions about the survey, after the perception questions	3.6% (2)	50.0% (1)	50.0% (1)

Most respondents dropped out either before starting the choice task or before answering the perception questions. The choice tasks and the perception questions were the most time-consuming parts of the survey, which could potentially explain the high drop-out rate around these sections of the survey. For both groups, a slightly bigger share of respondents received the introduction with both text and images.

However, due to the low number of respondents that dropped out and the quite small differences between the version of the introduction in terms of the number of respondents that dropped out, it cannot be concluded that the version of the introduction with both text and images led to a lower drop-out rate. If one wants to reduce the drop-out rate during the SP experiment, using both images and text in the introduction of the choice task thus might not the way to achieve that. However, no hard conclusions can be drawn based on the results of this thesis regarding the impact of the version of the introduction on drop-out.

9.3 Influence of the use of images in the introduction on preferences

To assess the impact of the different versions of the introduction on preferences, an additional parameter, β_{images}, was added to the utility function of HPT in the final panel ML model. This variable was dummy coded, with the text-only version of the introduction as the reference category. The used utility function for HPT is given by *Equation 9.1*. The utility functions for APT and HSR were not changed compared to the earlier presented final panel ML model (*Equations 7.11 and 7.12*).

$$
\begin{aligned}
V_{n,HPT} = \; & ASC_{HPT} + \beta_{TC} * TC_{HPT} + \beta_{IVT_{HPT}} * IVT_{HPT} + \beta_{WT_{HPT}} * WT_{HPT} + \beta_{ET_{HPT}} * ET_{HPT} \\
& + \beta_{BH_{HPT}} * BH_{HPT} + \beta_{images} * Intro + \upsilon_{n,land} + \beta_{comfort_{HPT}} * TripComfort_{HPT} \\
& + \beta_{experience_{HPT}} * Experience_{HPT} \\
& + \beta_{safety_{HPT}} * Safety_{HPT} + \beta_{frequency_{HPT}} * Frequency_{HPT} + \beta_{environment_{HPT}} \\
& * Environment_{HPT} + \beta_{speed_{HPT}} * Speed_{HPT} + \beta_{reliability_{HPT}} * Reliability_{HPT} \\
& + \beta_{income_{HPT}} * Income + \beta_{education_{HPT}} * Education + \beta_{purpose_{HPT}} * Purpose
\end{aligned} \tag{9.1}
$$

Again, 400 Halton draws were used to estimate the model. In *Table 14* the found parameter estimates for the panel ML model with the additional parameter for the choice context are presented. Also, the results from the final panel ML model are presented again, in order to make a clear comparison between the two models.

Table 14: Overview of parameter estimates of panel ML model with context parameter and of final panel ML model

Constant	Final panel ML model			Panel ML model with choice context parameter		
	Estimate	Standard error	t-value	Estimate	Standard error	t-value
ASC HSR	-8.219	0.844	-9.735	-8.148	0.937	-8.699
ASC HPT	-4.175	0.578	-7.226	-4.155	0.717	-5.794
Choice context variable						
Images in introduction	-	-	-	0.092	0.102	0.905
Attributes of the alternatives						
Travel cost	-0.017	0.001	-26.576	-0.017	0.001	-26.375
In-vehicle time APT	-0.009	0.004	-2.547	-0.009	0.004	-2.553
In-vehicle time HSR	0.0003	0.002	0.181*	0.0003	0.000	0.000*
In-vehicle time HPT	-0.0004	0.002	-0.210*	-0.0004	0.000	0.000*
Waiting time HPT	-0.011	0.003	-3.708	-0.011	0.003	-3.776
Egress time APT	-0.005	0.003	-1.739	-0.005	0.003	-2.023
Egress time HSR	0.003	0.003	1.154*	0.004	0.003	1.095*
Egress time HPT	0.002	0.002	0.723*	0.002	0.002	0.692*
Checked-in baggage APT	0.617	0.114	5.405	0.617	0.117	5.259
Checked-in baggage HSR	0.111	0.100	1.100*	0.109	0.135	0.809*
Checked-in baggage HPT	0.267	0.095	2.823	0.269	0.07	2.759
Sigma's for nesting structure						
Sigma land	1.943	0.146	13.307	1.940	0.148	13.079
Sigma existing	0.720	0.115	6.286	0.721	0.116	6.188
Perceptions towards HSR and HPT						
Trip comfort HSR	0.494	0.154	3.202	0.499	0.157	3.171
Trip comfort HPT	0.476	0.087	5.450	0.462	0.089	5.164
Safety HSR	0.187	0.145	1.294*	0.185	0.174	1.063*
Safety HPT	0.130	0.078	1.670	0.137	0.086	1.596*
Frequency HSR	0.052	0.000	0.000*	0.041	0.098	0.415*
Frequency HPT	0.015	0.000	0.000*	0.010	0.024	0.421*
Experience HPT	0.057	0.054	1.052*	0.057	0.060	0.946*
Environment HSR	0.295	0.101	2.927	0.289	0.101	2.865
Environment HPT	0.172	0.073	2.360	0.177	0.073	2.408
Reliability HSR	0.253	0.102	2.483	0.251	0.108	2.332
Reliability HPT	0.054	0.065	0.828*	0.050	0.107	0.469*
Speed HSR	0.217	0.101	2.145	0.214	0.104	2.060
Speed HPT	0.125	0.066	1.882	0.121	0.078	1.556*

Socio-demographic factors						
Income HSR	-0.009	0.000	0.000*	-0.009	0.009	-0.994*
Income HPT	0.073	0.027	2.701	0.072	0.029	2.463
Education HSR	0.415	0.116	3.582	0.414	0.118	3.522
Education HPT	0.312	0.078	4.012	0.310	0.079	3.930
Business HSR	-0.618	0.323	-1.912	-0.613	0.358	-1.709
Business HPT	-0.475	0.221	-2.150	-0.469	0.239	-1.958

The variable indicating the use of images of HPT in the introduction was dummy coded. The found parameter estimate thus indicates the additional utility of the group who received the introduction with both images and text compared to the group that received the text-only introduction. It was expected that respondents who received the introduction with both images and text would be more positive about HPT. However, the parameter estimate for the version of the introduction was found to be small, not significant and has a very large standard error compared to the size of the parameters. Given that the parameter estimate is not significant it can be concluded that using images of HPT in the introduction of the choice experiment is thus not of influence on the preferences of respondents and on the found results in this thesis. Adding this choice context parameter to the model also did not lead to significant improvement in model fit compared to the final panel ML model (LRS=0.8, df=1, p-0.371).

When comparing the found parameter estimates in the final panel ML model with the found parameter estimates in the model with additional choice context parameter, only small changes in the parameter estimates and its standard errors can be observed. However, no unambiguous differences between the two models were observed. Additionally, the values of constants for both HSR and HPT slightly changed due to the addition of the variable for the introduction with text and images of HPT. This could be explained by the fact that the value of the constant is influenced by adding variables to the model of which the average value is not zero, which is the case for the choice context variable. However, these changes in the value of both constants, due to the addition of the choice context variable to the model, is very small and thus almost neglectable.

9.4 Influence of the use of images in the introduction on the understanding of HPT

The impact of the different versions of the introduction on respondents' understanding of HPT was also studied. It was expected that respondents that received the introduction with both images and text would have a better understanding of HPT and would experience the explanation on HPT as clearer than respondents that had the text-only introduction. An independent sample t-test was used to determine whether or not a significant difference could be found among the two groups, in terms of how complete they find their image of HPT and of how clear they found the explanation on HPT in the introduction of the SP experiment. In *Table 15* the descriptive statistics of the asked questions regarding completeness and clarity and the results of the independent sample t-test are presented.

Table 15: Comparison of respondents with different versions of the introduction in terms of HPT explanation

Variable	Version of the introduction	Descriptive statistics			Independent sample t-test		
		Mean	Standard deviation	Absolute number	Difference	T-value	P-value
Complete picture of HPT	Text only	3.90	1.355	155	0.297	6.042	0.000
	Text & Images	4.19	1.210	150			
Clarity of explanation of HPT	Text only	3.74	0.744	155	0.151	5.828	0.000
	Text & Images	3.89	0.613	150			

When considering the descriptive statics, it can be observed that respondents that received the introduction with both images and text stated that they had a more complete picture of HPT and found the explanation of HPT clearer than respondents that received the introduction with text only.

Based on the results of the independent sample t-test it can be concluded that there is a significant difference between the group of respondents that received the text-only introduction and the group of respondents that received the introduction with both images and text in terms of how clear they experienced the explanation of HPT and of how complete they perceive their image of HPT to be. When interpreting these results, it should be noted that prior knowledge on HPT can also have influenced the outcomes, mainly for the question on how complete respondents perceive their image of HPT. However, given the significant difference between the groups that received a different version of the introduction, this prior knowledge is expected to have only played a small role, if at all.

Furthermore, two questions were included in the survey assessing respondents' knowledge of HPT by means of substantive questions regarding information that was provided in the introduction of HPT. One question was asked on the propulsion of HPT and the other question was whether travellers can look outside when travelling by means of HPT. Both questions were multiple-choice questions with 4 answer options, of which one was 'I don't know'. In *Table 16* the frequencies of the given answers to both questions are given, for the two different versions of the introduction. A distinction is made between the current answer, the wrong answer of the 'I don't know' -option.

Table 16: Descriptive statistics of the provided answers to the knowledge questions for the two versions of the introduction

Question	Version of the introduction	Provided answers			
		Correct	Wrong	I don't know	Total
Propulsion	Text only	115 (37.7%)	14 (4.6%)	26 (8.5%)	305(100%)
	Text & Images	132 (43.3%)	7 (2.3%)	11 (3.7%)	
	Total	247 (81.0%)	21 (6.9%)	37 (12.1%)	305 (100%)
In-vehicle experience	Text only	109 (53.8%)	9 (3.0%)	37 (12.1%)	305(100%)
	Text & Images	101 (33.1%	18 (5.8%)	31 (10.2%)	
	Total	210 (68.9%)	27 (8.8%)	68 (22.3%)	305 (100%)

For both questions, the largest group of respondents answered the questions correctly. For the propulsion question, the correct answer was given by 81% of the respondents, of which a slightly larger share received the introduction with both images and text. More interesting to note is that more than twice as many respondents with the text-only introduction gave the answer 'I don't know', compared to respondents with the text and images introduction. In the images the propulsion system was not shown. The respondent with both images and text introduction could thus not have seen the correct answer in the included images. However, using images could have caused respondents to stay focused more on the added text and could have improved understanding, forming a potential explanation for this found difference. For the question regarding the in-vehicle experience, the correct answer was given more often by respondents that received the text-only introduction. This was not expected, given that in the images that were presented in the introduction, also an image of the inside of the vehicle was included.

In order to assess if there indeed is a difference between the groups of respondents that received the different versions of the introduction in terms of how the substantive questions were answered, a Chi-square test was performed. The outcomes of the chi-square test are presented in *Table 17.*

Table 17: Results of the chi-square test

	Value	df	p-value (2-sided)
Propulsion	88.777[a.]	3	0.000
In-vehicle experience	35.800[b.]	3	0.000

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 35.41.
b. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 22.13.

Based on the results of the Chi-square test it can be concluded that there is a significant difference between the group of respondents that received the text-only introduction and the group of respondents that received the introduction with both images and text, in how the two substantive questions were answered. Including both images and text in the introduction of the choice experiment thus led to respondents answering the substantive questions better.

Furthermore, various notes can be made regarding the found results. Firstly, the high number of correct answers for both questions could also be caused by the fact that the knowledge question might have been too easy or too obvious. Secondly, in the introduction of the choice experiment, a button was added where respondents could click to have the information provided in the introduction accessible during the whole time when completing the survey. The large share of correct responses could thus also be explained by the fact that respondents looked up the correct answers to the knowledge questions, instead of actually remembering it from reading the introduction at the beginning of the survey. Besides that, respondents could have had prior knowledge on HPT, impacting the way in which they answered the knowledge questions.

In conclusion: if one wants to reduce the drop-out rate during SP experiments, using both images and text in the introduction of the choice task might not be the way to achieve that. However, using images díd improve the understanding of HPT by respondents. Using images to explain something people are unfamiliar with, thus can be helpful to improve understanding of that concept. This insight is useful for scientific purposes but can also be applied outside the world of science.

9.5 Influence of the use of images in the introduction on perceived similarity of HPT with either APT or HSR

The impact of the different versions of the introduction on whether respondents see HPT as more similar to APT or to HSR was also analysed. It was expected that respondents who received the introduction of HPT with both images and text would see HPT as more similar to HSR than to APT. Reason for this is that the presented images show the station lay-out of HPT and vehicle lay-out of HPT, which is more similar to HRS than to APT. Besides that, it was expected that respondents that received the text-only introduction of HPT would see HPT as more similar to APT, given that HPT is more similar to APT in terms of non-visual characteristics.

Whether or not these expectations were met was assessed by estimating four different variations of the final panel ML models. In two models only an additional error component was added to both APT and HPT, the air error component. In the other two models, the additional error component was only added to the utility functions of HSR and HPT, the land error component. The error components were thus added separately to the models. The error component for existing modes was left out of the model for this analysis. One of the models with each error component was estimated on data with only responses of people that received the text-only introduction, the other model for each error components was estimated on data with only responses of respondents that received the text and images introduction. The four different panel ML models were estimated using 400 Halton draws, given that this led to stable estimates for the σ's. A comparison of the model performance of the four models is presented in *Table 18*.

Table 18: Model performance for the models with different error components on data with either text only introduction or text and images introduction

Error component	Data used	LL (final)	Adjusted ρ^2	σ[35]	t-value of σ
Land	Text only introduction	-1039.694	0.300	1.467	9.950
	Text & Images introduction	-946.808	0.339	1.293	9.171
Air	Text only introduction	-1067.243	0.282	1.380	8.821
	Text & Images introduction	-977.276	0.319	1.035	6.872

When considering results from *Table 18*, it can be seen that the final Log-Likelihoods for the models with the text and images introduction are substantially lower than the final Log-Likelihoods for the models based on the text-only data. This indicates a better model fit for the text and images introduction data than for the text only data. All four σ's that were estimated are significant.

A larger standard deviation of an error component, σ, implies more importance of that nest and indicates that people see the alternatives within the nest as more similar to each other, and as more different compared the alternatives outside the nest. The σ's that were found in the two models based on the text-only introduction, thus one model with the land error component and one model with the air error component, are relatively similar. Indicating that land nest and the air nest are equally important. People who received the text only introduction thus do not see HPT as more similar to APT. The set expectation is thus not met.

However, in the two models that were based on the text and images data, thus one model with the land error component and one model with the air error component, substantially different σ estimates were found. The value for σ_{land} was found to be larger than the value for σ_{air}, implying that

[35] σ= the standard deviation of the error component.

the nest with HSR and HPT is more important than the nest with APT and HPT. People that received the introduction with both images and text thus see HPT as more similar to HSR than to APT. This is in line with the set expectation. How a certain mode looks thus could play a role in its positioning compared to other modes of transport and potentially impacts its competitive position.

9.6 Summary

For both versions of the introduction almost the same number of responses were present in the data set. No effect of the use of images in the introduction of HPT in the SP experiment on drop-out was found. However, when looking at the questions asking respondents how complete their image and understanding of HPT was after the survey, it was found that the version of the introduction with both images and text led to a better understanding of HPT.

Moreover, a significant difference was found between the groups of respondents that received the two versions of the introduction in terms of how the substantive questions were answered. Lastly, it was found that respondents that received the introduction with both images and text see HPT as more similar to HSR than to HPT. The expectation that respondents that received the text only introduction would see HPT as more similar to APT was not met.

10. The design of the hyperloop system

The aim of this thesis is to assess the impact of different design scenarios of HPT on travellers' preferences and mode choice, and on travel demand for APT, HSR and HPT for long-distance transport within Europe. In paragraph 10.1 the impact of different HPT design aspects on potential market shares for APT, HSR and HPT is analysed. In paragraph 10.2 these design aspects are combined into design scenarios, in which the potential market shares of APT, HSR and HPT are defined. It was also studied in which of the proposed design scenarios the surplus in passenger demand at AAS, which is expected to be in place in WLO scenario high, could potentially be dealt with. After that, it is discussed whether there is alignment between the design scenarios that are most preferred from a traveller perspective and those design scenarios that are made most likely from a stakeholder perspective. This is discussed in paragraph 10.3. Paragraph 10.4 gives a summary of this chapter. In this chapter, the MNL model is used instead of the panel ML model.

10.1 Design scenarios

10.1.1 Design aspects

In chapter 4 of this thesis, three main design uncertainties were identified, based upon the stakeholder interviews that were conducted. These design uncertainties form the basis for the construction of different HPT design scenarios. The design of HPT is varied in terms of three aspects: the location of the HPT station, whether or not security checks are in place and the type of security checks used, and whether or not baggage can be checked in. In *Table 19* an overview is given of the different design options for HPT that are taken into account for each of the identified design uncertainties. Also, the effect of the different design options on the different attributes that were included in the choice experiment can be found in *Table 19.*

Table 19: Design options for HPT system design

Design aspect	Included design options	Attributes	Attribute levels[36]
Location of the HPT station	At AAS	In-vehicle time & waiting time	IVT = +15 minutes, WT = + 10 minutes
	In 15-min reach from the city	In-vehicle time	IVT = no additional minutes
Security checks	No security checks	Waiting time	WT = 15 minutes
	Security check light		WT = 30 minutes
	Elaborate security checks		WT = 45 minutes
Checked-in baggage	No option for baggage check-in	Checked-in baggage	No checked in baggage
	Baggage is checked-in		Checked-in baggage

The location of the HPT station is of influence on the in-vehicle time of HPT and on the waiting time of HPT. Waiting time has been defined as the time that travellers need to wait before or in between the different components of the trip, due to e.g. security checks, checking-in their baggage, walking at the station/airport or the time that travellers arrive at the station/airport before departure of their trip. When HPT is located at AAS, 15 minutes additional in-vehicle time and 10 minutes of additional waiting time are taken into account, compared to the situation in which the HPT station is located 15 minutes from the city centre. The reason for including this additional in-vehicle time can be found in the fact

[36] IVT = In-vehicle time, WT= waiting time, CB = checked-in baggage

that AAS is located about 30 minutes outside the city of Amsterdam and thus requires passengers to travel longer to get to AAS. [37] The 10 minutes of additional waiting time are included because walking distances at AAS, from the location of arrival at AAS to the location of departure of HPT, are expected to be longer than at a dedicated HPT station. Waiting times for APT and HSR were fixed in the choice experiment to respectively 2 hours and 15 minutes. Therefore, no additional waiting time is included for these modes when departing from AAS. [38]

Furthermore, when no security check is in place, it is assumed that on average people arrive 15 minutes before departure at the station, in order to make sure they do not miss their international transport. This assumption is based on the current HSR system. Security check light indicates a security check that is less time consuming than in the current APT security check. Technological developments play a key role to facilitate this form of security checks. A 30-minute waiting time is taken into account for the light security check. In the case of an elaborate security check, 45 minutes of waiting time were included.

In the design option where baggage is checked-in, no additional waiting time is taken into consideration, even though waiting time is impacted by this. The reason for doing so is that the attribute of checked-in baggage has been measured explicitly in the choice experiment. This design aspect is directly included in the design scenarios by means of that attribute. For APT it is assumed that baggage is checked in, for HSR no checked-in baggage is assumed, given that these are the most realistic options for both modes of transport.

Since AAS is considering HSR and HPT as potential modes to reduce the number of flights at AAS and to be able to deal with the expected growth in travel demand predicted in WLO scenario high (CPB & PBL, 2015), it is interesting to study whether HPT would potentially take away market share from APT, and to what extent this is the case. According to WLO scenario high, AAS will not be able to deal with a quarter of the passenger demand (42,5 million passengers). The role of the different design aspects on the market position of HPT should be taken into consideration when designing the HPT system. The situation in which only APT and HSR are in place forms the reference scenario. From there on, the impact of different HPT design scenarios on the market shares for APT, HSR and HPT for journeys around 500 km distance, with both origin and destination in Europe can be assessed. This was done based on the estimated MNL model.[39]

Several remarks need to be made regarding the use of the MNL model instead of the ML model. The MNL model assumes proportional substitution, implying that HPT would, percentagewise, take away market share equally from APT and HSR in proportion to the found utilities for both modes. However, in the estimated panel ML model there was found that passengers see HPT as more similar to HSR than to APT. HPT is thus more in competition with HSR than in with APT. This should be kept in mind when considering the rest of this chapter since this will not be reflected in the scenario analysis. Besides that, since the MNL model is used, a binary comparison between APT and HSR can be made by means of the model. This allows comparing the current situation with only APT and HSR with the possible future situation with APT, HSR and HPT.

[37] This is under the assumption that travellers weigh additional egress time in the same way as they would weigh access time. In reality, access time may be weighed differently than in-vehicle time for main transport.
[38] Underpinning for the included attributes and attribute levels can be found in Chapter 5.
[39] The fact that the MNL model allows calculating market shares only taking into account APT and HSR forms a motivation for using the MNL model instead of the panel ML model.

When using the MNL model to assess the impact of the different design uncertainties on the market shares for APT, HSR and HPT several assumptions regarding the socio-demographic characteristics and the perceptions towards HSR and HPT were made. The socio-demographics that are included in the utility function of HSR and HPT were fixed to their most frequently occurring level in the sample and perceptions are set to the middle level.[40] All attributes were set to their middle attribute level.[41] In *Figure 6* an overview is given of how the design uncertainties, socio-demographics and perceptions are of influence of the potential market shares of APT, HSR and HPT.

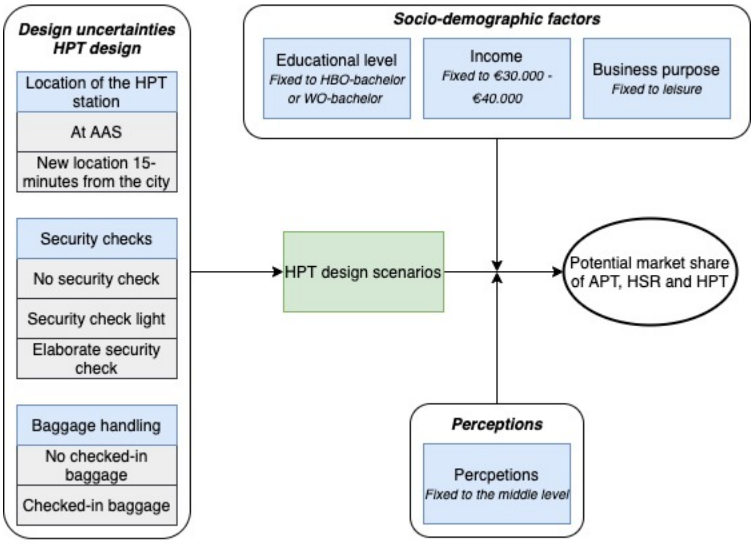

Figure 6: Overview of aspects influencing the potential market share of HPT

Before constructing different design scenarios for HPT, based on the identified design uncertainties, a sensitivity analysis was performed. The aim was to assess the impact of changes in the attribute level of only one attribute of HPT on the potential market shares for APT, HSR and HPT. The impact on the market shares of one unit of change in a certain attribute level for HPT is analysed, as well as the impact of the various attribute levels that were included in the choice task. Results are presented in *Table 19.* The reference scenario is the situation with only APT and HSR in place. The base case is the situation in which HPT is introduced as well and all attribute levels for all three alternatives are set to their middle level. Socio-demographics are set to their most frequently occurring level and perceptions are set to the middle level as well.

[40] Educational level is fixed to HBO-bachelor or WO-bachelor, income is fixed to €30.000 - €40.000 and trip purpose is fixed to leisure purpose.
[41] Travel cost (APT, HSR & HPT) = 110, In-vehicle time (HSR &HPT)= 01:05 (hh:mm), In-vehicle time (HSR) = 03:15 (hh:mm) waiting time (HPT)= 00:25 (hh:mm), egress time(APT, HSR & HPT) = 00:30 (hh:mm), APT = checked in baggage, HSR = no checked-in baggage, HPT = no checked-in baggage. The included attribute levels and the line of reasoning to come to these attribute levels can be found in paragraph 5.2.2 of this thesis.

Table 20: Sensitivity analysis of changes in attribute levels on the market shares for APT, HSR and HPT[42]

Attribute	Attribute level	Market share APT	Market share HSR	Market share HPT
Reference scenario[43]		70.2%	29.8%	-
Base case		41.4%	19.4%	38.2%
Travel cost HPT	€1 increase HPT	41.7%	19.5%	38.8%
	€1 decrease HPT	42.2%	19.3%	38.5%
	€35	23.6%	10.8%	65.6%
	€110	41.4%	19.4%	38.2%
	€185	57.2%	26.2%	16.7%
In-vehicle time HPT[44]	1 min increase HPT	42.5%	19.4%	38.1%
	1 min decrease HPT	42.4%	19.4%	38.3%
	00:45	41.1%	18.8%	10.1%
	01:05	41.4%	19.4%	38.2%
	01:25	43.7%	20.0%	36.3%
Waiting time HPT	1 min increase HPT	42.5%	19.5%	38.0%
	1 min decrease HPT	42.3%	19.3%	38.4%
	00:15	39.1%	17.9%	43.0%
	00:35	41.4%	19.4%	38.2%
	00:55	45.6%	20.9%	33.6%
Egress time [45]	1 min increase HPT	42.4%	19.4%	38.2%
	1 min decrease HPT	42.4%	19.4%	38.2%
	00:05	43.2%	19.8%	37.0%
	00:30	41.4%	19.4%	38.2%
	00:55	41.6%	19.0%	39.4%
Checked-in baggage	No checked-in baggage	41.4%	19.4%	38.2%
	Checked-in baggage	38.7%	17.7%	43.6%

Based on the performed sensitivity analysis, several notes should be made. When comparing the reference scenario and the base case, it can be observed that APT loses more percentage points in market share than HSR, due to the introduction of HPT. This is logical given the initial larger market share of APT and due to the proportion substitution, that is assumed in the MNL model. Overall, APT has the largest potential market share when comparing APT, HSR and HPT. The situation in which an HPT ticket costs €35 and the tickets for APT and HSR both cost €110, is the only case in which the

[42] Results are generated based on the MNL model, assuming proportional substitution. The finding from the panel ML model that HPT is seen as more similar to HSR than to APT and thus is more in competition with HSR than with HPT is not taken into account in the presented sensitivity analysis.
[43] Travel cost (APT, HSR & HPT) = 110, In-vehicle time (HSR &HPT)= 01:05 (hh:mm), In-vehicle time (HSR) = 03:15 (hh:mm) waiting time (HPT)= 00:25 (hh:mm), waiting time (HSR) = 00:15 (fixed), waiting time (APT) = 02:00 (fixed)egress time(APT, HSR & HPT) = 00:30 (hh:mm), APT = checked in baggage, HSR = no checked-in baggage, HPT = no checked-in baggage. Educational level is fixed to HBO-bachelor or WO-bachelor, Income is fixed to €30.000 - €40.000 and trip purpose is fixed to leisure purpose. This is the case in both the reference scenario and the base case.
[44] The parameter estimates for in-vehicle time for HPT and HSR are very small, not significant and in a counterintuitive direction. One should thus be careful when drawing conclusions regarding this parameter.
[45] The parameter estimates for egress time for HPT and HSR are very small, not significant and in a counterintuitive direction. No hard conclusions can thus be based upon these parameter estimates.

potential market share of HPT becomes larger than the potential market share of APT. In all other cases, APT has the largest potential market share in the transport market with APT, HSR and HPT, for OD-trips within Europe of approximately 500 km. Furthermore, the market share of HPT most sensitive to changes in the travel cost of HPT, ceteris paribus. Making HPT tickets cheap compared to APT and HSR thus leads to a larger potential market share of HPT. If HPT tickets would become more expensive, this would lead to a rapid decrease in the potential market share of HPT.

After insights were generated regarding the impact of changes in attribute levels of individual attributes on the market shares of APT, HSR and HPT, it was assessed how the market shares for the three modes change due to changes in one of the design aspects of HPT. *Table 21* provides an overview of the market shares for APT, HSR and HPT in case only one of the design aspects of HPT is varied. Again, the reference scenario is the situation in which only APT and HSR are in place.

Table 21: Market shares of APT, HSR and HPT based on varying only one design aspect of HPT

Design option	Attributes[46]	Attribute levels	Market share APT	Market share HSR	Market share HPT
Reference scenario[47]			70.2%	29.8%	-
Base case			41.4%	19.4%	38.2%
		Location of the station			
At AAS	IVT & WT	IVT = 60 WT = 25	40.4%	18.5%	41.1%
		IVT = 80 WT = 45	45.0%	20.4%	34.5%
15 min reach from the city	IVT	IVT = 45	41.1%	18.8%	40.1%
		IVT = 65	41.4%	19.4%	38.2%
		IVT = 85	43.7%	20.0%	36.3%
		Security check			
No security check	WT	WT = 15	39.1%	17.9%	43.0%
Security check light		WT = 30	41.6%	19.0%	39.4%
Elaborate security check		WT= 45	44.0%	20.1%	35.9%
		Baggage handing			
No checked-in baggage	BC	BH = 0	41.4%	19.4%	38.2%
Checked-in baggage		BH = 1	38.7%	17.7%	43.6%

When considering the two options for the location of the HPT station, locating HPT at AAS with short in-vehicle times and a smooth, not very time consuming, process at AAS in terms of waiting time, could lead to the largest potential market share for HPT (41.1%), when only looking at the impact of the location of the HPT station. However, if in-vehicle times become longer and if waiting time increase due to e.g. longer walking distances at AAS, locating HPT at AAS leads to the lowest market share (34.5%)

[46] IVT = in-vehicle time, WT = waiting time, BC = Checked-in baggage

[47] In the reference scenario all attribute levels are set to their middle level: Travel cost = 110, In-vehicle time (APT)= 01:05, In-vehicle time(HSR) = 03:45 (hh:mm), waiting time = fixed (02:00 for APT & 00:15 for HSR), egress time = 00:30 (hh:mm), checked-in baggage for APT and no checked-in baggage for HSR. Educational level is fixed to HBO-bachelor or WO-bachelor, Income is fixed to €30.000 - €40.000 and trip purpose is fixed to leisure purpose.

for HPT, when considering the impact of changes in each of the design aspects. When HPT is located at AAS, minimization of the in-vehicle time and waiting time is thus crucial for the potential market share of HPT for OD trips.

In terms of the type of security checks used in the HPT system, using an elaborate security check leads to a reduction of 7.1 percentage points of the potential HPT market share compared to the situation without a security check. Moreover, the type of security check that is included in the HPT design, if at all, leads to the largest variety in potential market shares of HPT, when comparing the different design aspects. The effect of the type of security checks, if at all, on the potential market share for HPT was thus found to be large. This is not surprising, given that the form of security checks is of impact on waiting time and waiting time has the large utility contribution of all included attributes for HPT.

In terms of baggage handling, having the option to have checked-in baggage leads to larger potential market shares of HPT compared to when baggage cannot be checked in. This is in line with the found positive utility contribution of having checked-in baggage. Having checked-in baggage for HPT leads to an increase of 5.4 percentage points in the potential market share of HPT.

10.1.2 Scenario estimation

Based on the different design options that came forward during the stakeholder interviews, four design scenarios have been constructed. When constructing the different design scenarios, the same assumptions were applied as those used for assessing the impact of the individual design aspects on the potential market shares.[48] The attribute levels that were used in the different scenarios can be found in *Table 22*. The different design scenarios are discussed in more detail below and are visualised in *Figure 7* to *Figure 10.*

Table 22: Overview of attribute levels for the different HPT design scenarios

Attributes	Reference scenario	1.HPT as the faster HSR	2. HPT as the sustainable plane	3.HPT as completely new system	4. HPT as part of the multimodal hub AAS
Travel cost	No HPT in place, attribute levels of APT and HSR are set to their middle attribute level	110	110	110	110
In-vehicle time		01:05	01:20	01:05	01:20
Waiting time		00:15	00:55	00:30	00:40
Egress time		00:30	00:30	00:30	00:30
Checked-in baggage		No checked-in baggage	Checked-in baggage	No checked-in baggage	Checked-in baggage
Perceptions	All set to 3 (middle level)				
Income	€30.000 - €40.000				
Education	HBO-bachelor or WO-bachelor				
Trip purpose	Leisure				

[48] All attributes are set to their middle level, perceptions are set to their middle level and socio-demographics are fixed to their most frequently occurring category (in the sample).

Scenario 1: HPT as the faster HSR

In this scenario, HPT is designed with the current HSR system as a reference. The station is located 15 minutes from the city centre and is very well connected to the rest of the transport network in the Netherlands. No security check is in place. Therefore, no additional waiting time is taken into account for that. Baggage check-in is not possible in this scenario, baggage is thus accessible to travellers during the whole trip.

Figure 7: Visualisation HPT design scenario 1

Scenario 2: HPT as the sustainable plane

In this scenario, the design of HPT is comparable to the current APT system. The HPT station is located at AAS and an elaborate security check is in place, requiring travellers to be present at AAS about one hour before departure of the HPT. This longer waiting time is not only due to the security checks but also due to the longer walking distances at AAS, from the location where passengers arrive at AAS to where HPT departs at AAS. In terms of baggage handling, baggage is check-in and small hand baggage is allowed.

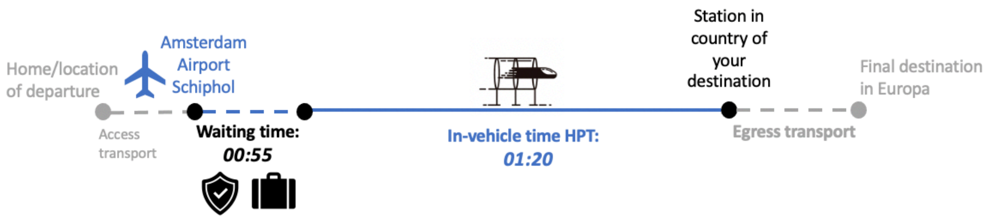

Figure 8: Visualisation HPT design scenario 2

Scenario 3: HPT as completely new system

In this, a new location for the HPT station is created from which the city of Amsterdam is accessible in 15 minutes. Due to the international character of the journeys made by means of HPT, a security check light is in place. The technology used for these security checks is quite advanced, leading to only 30 minutes of additional waiting time. It is not possible to have checked-in baggage, all baggage is thus accessible to the traveller during the whole journey.

Figure 9: Visualisation HPT design scenario 3

Scenario 4: HPT as part of the multimodal hub AAS

In this scenario, an HPT station is located at AAS, given that this is one of the main multimodal hubs for passenger transport within Europe. Only security check light is in place, requiring travellers to be present at AAS 30 minutes before departure. Due to the fact that HPT is located at AAS, 10 minutes of additional waiting time need to be added to that for walking time at AAS. Besides that, baggage can be checked-in in this scenario.

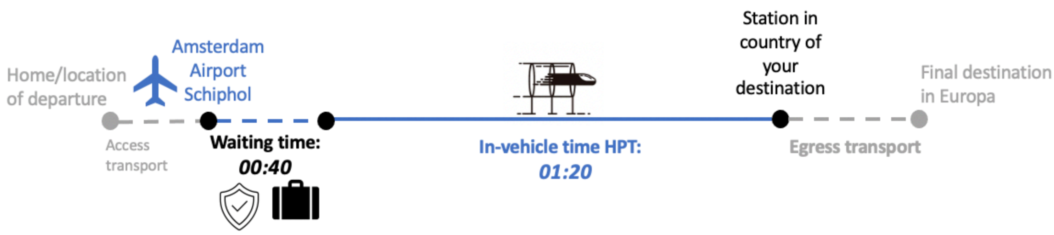

Figure 10: Visualisation HPT design scenario 4

The potential market shares for APT, HSR and HPT in the different design scenarios can be found in *Table 23.*

Table 23: Found market shares in the different HPT design scenarios

Scenarios	Market share APT	Market share HSR	Market share HPT
Reference scenario	70.2%	29.8%	-
Scenario 1: HPT as the faster HSR	39.1%	17.9%	43.0%
Scenario 2: HPT as sustainable plane	43.0%	19.7%	37.4%
Scenario 3: HPT as completely new system	45.6%	20.8%	33.6%
Scenario 4: HPT as part of the multimodal hub AAS	40.5%	18.5%	40.9%

When considering the found market shares in the different scenarios, the conclusion is warranted that HPT can potentially have a quite large market share for OD-transport in Europe in the transport market with only APT, HSR and HPT. In design scenario 1 and 4 HPT is the dominant alternative in terms of the potential market share, in design scenario 2 and 3 APT has the largest potential market share.

It is interesting to note is that scenario 4 is the second-best performing design scenario for HPT in terms of potential market share, despite the fact that the HPT station is located at AAS in this scenario. Possible explanations for this could be found in the fact that only security check light is in place, leading to only a small increase in waiting time, and in the fact that baggage can be checked in. Checked-in baggage has a positive contribution to utility and thus makes the HPT alternative more attractive. This positive utility contribution related to having checked-in baggage could partly compensate the negative utility related to the location at AAS.

The market share for HPT only varies with 9.4 percentage point among the different HPT design scenarios. This could be explained by two different aspects. Firstly, this could be caused by having made too small changes to the design, differentiating the scenarios from each other only to a small extent. Secondly, this could be caused by the small utility contributions that were found for in-vehicle time for HPT, given that this attribute plays an important role in how the different design scenarios were varied.

When comparing both of the scenarios in which HPT is located at AAS, scenario 2 and scenario 4, it can be seen that the type of security check that is applied, has a crucial impact on the potential market shares of HPT. This can also be concluded based on the comparison of the two scenario's that are located at a new location within 15 minutes reach from the city, scenario's 1 and scenario 3, given that the only difference between these design scenarios is the presence of security check light or not. Having a security check light in place compared to no security check at all leads to a decrease in potential market share for HPT of 9.4 percentage points.

Figure 11 to *Figure 14* visualise the impact of changes in one attribute for HPT only on the potential market shares for APT, HSR and HPT in the different design scenarios. Despite that one attribute of HPT that is changed in a design scenario, no changes are made to other aspects of the APT, HSR or HPT alternative. It is important to keep in mind when reading the following results for each of the scenarios and when looking at *Figure 11* to *Figure 14,* that these results are only applicable for OD passengers (not for transfer passengers), for journeys around 500 km within Europe, and only taking APT, HSR and HPT into account.

Scenario 1: HPT as the faster HSR

In scenario 1 the potential market share of HPT is found to be the largest compared to the other included design scenarios, namely 43.0%. Scenario 1 is thus the most promising design scenario for HPT, especially since the potential market share of HPT is larger than the potential market share of APT in this scenario. Reason for this could be that no additional waiting time for security checks or for additional walking time at AAS is needed in this scenario. The impact of changes in waiting time in this scenario on the potential market shares for APT, HSR and HPT is visualised on the bottom left graph in *Figure 11.* When reducing the waiting time of HPT, more percentage points of market share are taken away from APT than from HSR. Since HPT is located at its own station, not leading to additional waiting time since no security check is in place and since baggage cannot be checked-in, waiting time could be brought back to a minimum in this scenario.

Changes in waiting time have a larger effect on the market shares than changes in in-vehicle time. An increase or decrease in the in-vehicle time of HPT does only have a small impact on changes in the potential market shares of APT, HSR and HPT (top right graph in *Figure 11).* However, the found parameter estimate for in-vehicle time for HPT was only very small and not significant. No hard conclusions can thus be drawn from that.

Travel cost forms an important aspect of the optimization of this design scenario, which could be explained by the high utility contribution for travel cost that was found in the MNL model. The impact of changes in travel cost for HPT on the potential market shares for the different modes is visualised in the top left graph in *Figure 11.* Low travel costs for HPT, ceteris paribus, could lead to a potential market share for HPT of around 80%. However, when travel cost increase, this immediately leads to a reduction of the potential market share of HPT, mainly taken away by APT in terms of number of percentage points. When the ticket price for HPT become around €150, APT and HPT have almost the same market share, around 40%.

Allowing checked-in baggage in this scenario could increase the potential market share for HPT even further, from 43.0% to 48.6%. The effect of changes in whether or not baggage can be checked-in on the potential market shares of APT, HSR and HPT in scenario 1 is presented in the bottom right graph in *Figure 11.*

Thus, in order to optimize this first design scenario, changes in travel cost are of large impact and ticket price should thus be determined carefully. Waiting time also plays a substantial role. By creating a smooth and fast process for the passenger flows, waiting time can be minimized and the potential market share for HPT could be increased. Lastly, allowing checked-in baggage would lead to a further increase of the potential market share of HPT.

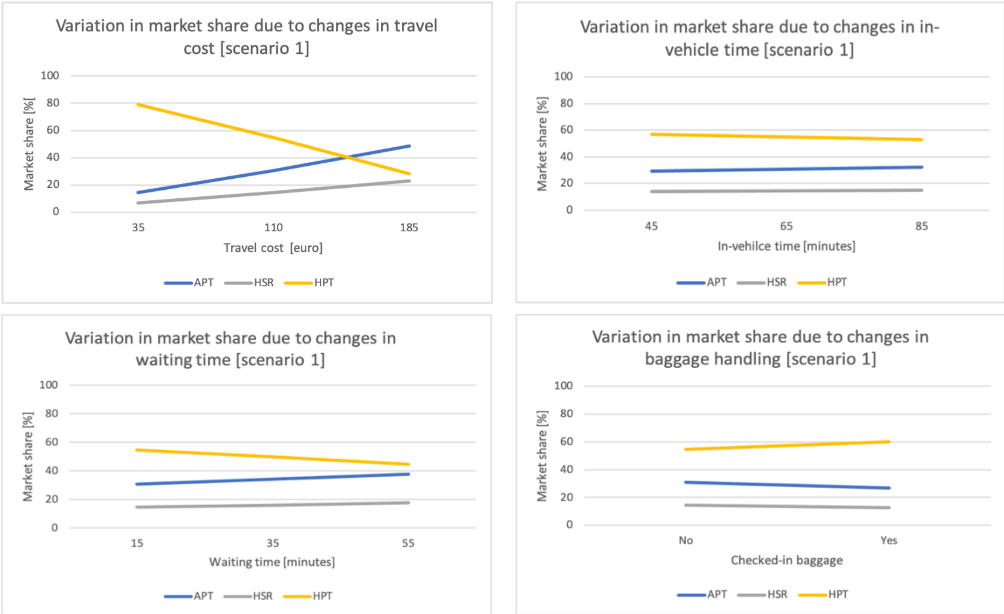

Figure 11: Variation in market share due to changes in-vehicle time, waiting time and travel cost in scenario 1

Scenario 2: HPT as the sustainable plane

In this scenario, HPT is designed in a similar way as the current APT system. This design scenario led to a quite small potential market share for HPT (37.4%), when comparing the different design scenarios. In this scenario the longer in-vehicle times and quite long waiting time, due to both the location at AAS and elaborate security checks, are mainly responsible for this lower potential market share of HPT. Visualisations of the impact of changes in the attribute levels of only one attribute of HPT on market shares for APT, HSR and HPT in this scenario are presented in *Figure 12.*

When looking at the top left graph in *Figure 12,* it can be observed that again travel cost has a large impact the potential market shares in this second scenario. Reductions in travel cost of HPT lead to a substantial increase in the potential market share for HPT. An increase in ticket price thus leads to substantial losses in market share. If HPT ticket prices become too high, APT becomes the dominant mode of transport in the market for journeys around 500 km with both origin and destination in Europe.

The impact of changes in in-vehicle time of HPT on the potential market shares for HSR, HPT and APT is limited, as can be seen in the top right graph in *Figure 12*. If one wants to optimize this design scenario, trying to reduce in-vehicle time thus will only lead to small gains in percentage points of potential market share. However, in-vehicle time was found to be not significant. One should thus be very careful when warranting conclusions regarding this attribute.

Again, the potential market shares in this scenario are more sensitive to changes in waiting time. Since HPT is located at AAS and an elaborate security check is in place in this scenario, minimizing waiting time can be a complex matter. Reducing waiting time in this scenario will thus only be possible within limits. The elaborate security check could maybe be performed in a little less time than 45 minutes, but large time reductions in waiting time will be hard to achieve, with only small gains in potential market share for HPT as a consequence. However, trying to smoothen the passenger flows in this scenario with the aim of minimizing waiting time, is worthwhile to do. The impact of changes in waiting time on the potential market shares is visualised in the bottom left graph in *Figure 12.* All in all, in order to optimize the potential market share of HPT in design scenario 2 ticket prices should be kept low and waiting time should be minimized when possible.

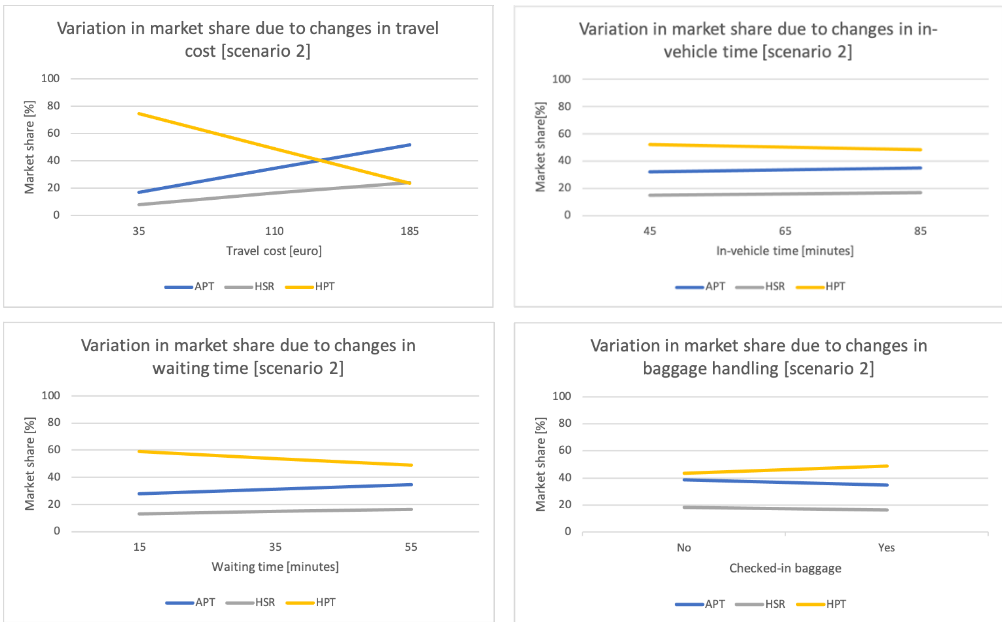

Figure 12: Variation in market share due to changes in in-vehicle time, waiting time and travel cost in scenario 2

Scenario 3: HPT as completely new system

The fact that a security check light is in place, instead no security check at all, is the only difference between this scenario and scenario 1. However, this difference in the design of HPT is what makes design scenario 3 the design scenario in which HPT has the smallest potential market share (33.6%). This difference between the two designs is of influence on waiting time and the limits in which reductions in this time component are possible. Moreover, technology plays a key role in performing the security check light and further developments regarding that technology could thus also lead to further reduction in waiting time. Changes in this thus largely depend on developments by external parties. When taking a look at the bottom left graph in *Figure13*, it can be seen that a decrease in waiting time would lead to an increase of potential market share for HPT, mainly taking away percentage points of market share from APT.

Furthermore, dynamics in terms of how to optimize this design regarding in-vehicle time and travel cost are similar to design scenario 1. The impact of changes in travel cost for HPT on the potential market shares are visualised in the top left graph in *Figure 13*, visualisation of the impact of changes in in-vehicle time of HPT on the potential market shares of APT, HSR and HPT can be found in the top right graph in *Figure 13* and the effect of changes in whether baggage can be checked in or not is visualised in the bottom right graph in *Figure 13.*

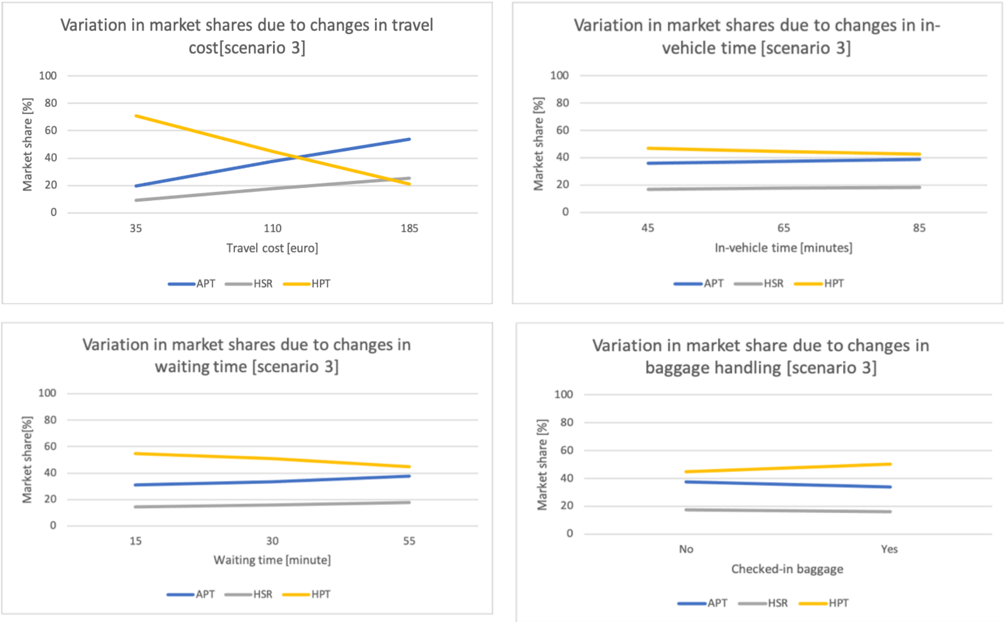

Figure 13: Variation in market share due to changes in in-vehicle time, waiting time and travel cost in scenario 3

Scenario 4: HPT as part of the multimodal hub AAS

Despite the fact that HPT is located at AAS in this scenario, this design scenario is the second-best option in terms of the potential market share for HPT (40.9%). HPT also is the dominant mode in terms of potential market share in this scenario. This is mainly caused by the utility contribution of having checked-in baggage (bottom right graph in *Figure 14)*. An elaborate security check is in place, which provides the opportunity to only slightly reduce waiting time. However, doing so depends on other parties and further developments in technology. Reductions in in-vehicle time again are only of small influence on the market share for HPT and changes in travel cost are of large impact on the potential market shares. The impact of changes in the in-vehicle time of HPT is visualised in the top right graph in *Figure 14.*

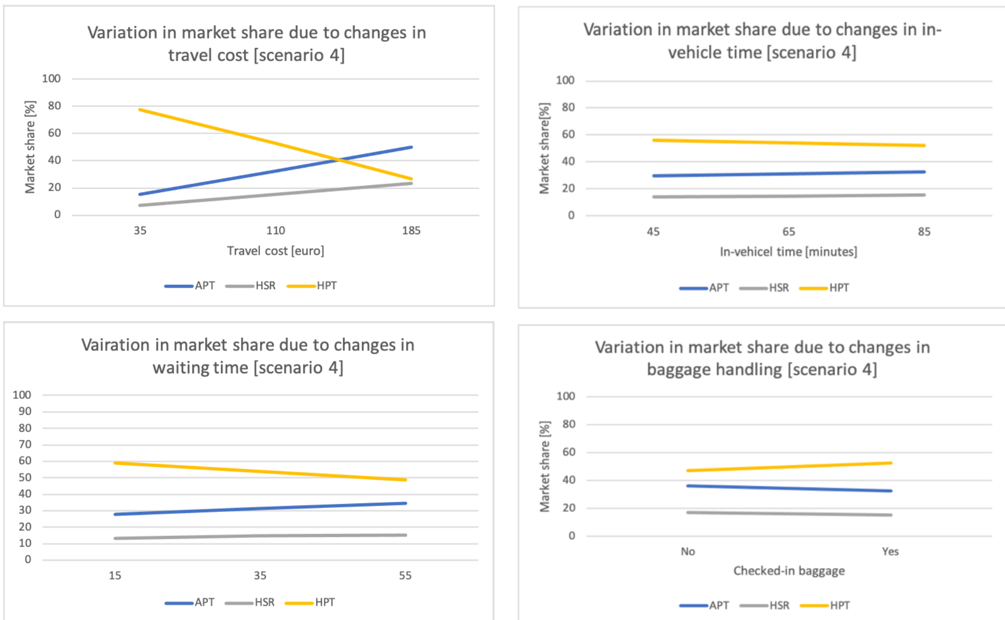

Figure 14: Variation in market share due to changes in in-vehicle time, waiting time and travel cost in scenario 4

In conclusion, scenario 1, HPT as the faster train, and scenario 4, HPT as part of the multimodal hub AAS, are the two scenarios that lead to the largest potential market share for HPT, when taking only the travellers' perspective into account. Found potential market shares for HPT were respectively 43.0% and 40.9%. Travel cost, and thus ticket price, has is very important role in optimizing the potential market share for HPT. Small changes in travel cost are of large impact on the market share of HPT.

Moreover, in-vehicle time only has a very small impact on the potential market share of HPT. However, this parameter estimate was not significant. No hard conclusions can thus be drawn.

Waiting time on the other hand, should be taken into consideration seriously in these design scenarios. When no security checks are in place, this waiting time could be minimized more easily than when security check light or elaborate security checks are chosen. Improvements regarding security check light depend largely on third parties, due to the technological component, but does provide an opportunity for both ensuring a safe system and at the same time keeping the additional waiting time related to that within limits. However, when HPT is located at AAS additional waiting times due to larger walking distances at AAS will always remain, limiting the extent to which waiting time can be minimized. Focussing on creating a smooth passenger flow could help in minimizing the waiting time related to walking distances at AAS.

Lastly, having checked-in baggage is preferred from a traveller perspective. However, if baggage handling is poorly organized and this leads to an increase in waiting time, the increase in potential market share due to the service of having checked-in baggage is partly diminished by the reduction in potential market share for HPT due to longer waiting times. This thus is a thin line.

When considering the outcomes of the different design scenario's various aspects that are not measured in the model, should also be kept in mind. Firstly, people already have an association and experience with travelling from AAS. This could impact mode choice of travellers. Secondly, when HPT is located at AAS, having an elaborate security check would feel less strange for travellers compared to having a heavy security check at e.g. a new location or an existing train station. When an entirely new location is created for HPT, travellers have less prejudices and expectations on how travelling by means of HPT will be organised. Thirdly, in the current design scenarios no distinction is made between locating HPT at an entirely new location or locating it at e.g. the train station of Amsterdam Zuid. Forth, when HPT is located at a location closer to the city, using HPT could be seen as more low-key and part of more routine transport than when HPT would be located at AAS. Locating HPT at AAS could create a threshold for people in terms of ease of use. Fifth, the combination of having no security check and having checked in baggage is not taken into consideration, given that this is expected to be unlikely to happen. When baggage is being checked and thus checked for security reasons as well, this would go hand in hand with a form of security checks for travellers as well. The same line of reasoning can be applied for no checked-in baggage but including an elaborate security check.

10.1.3. Can the expected travel demand in WLO scenario high be dealt with?

Based on the potential market shares for HPT in the different design scenarios it can be assessed whether or not it will be possible to deal with the expected increase in travel demand at AAS in WLO scenario high (CPB & PBL, 2015). In WLO scenario low, no traveller surplus is expected to occur. In WLO scenario high on the other hand, this is expected to be the case. A travel demand of 170 million passengers in 2050, of which 107.4 million are OD-passengers, is expected in this scenario.[49] It is foreseen that AAS cannot deal with a quarter of the total expected number of passengers, thus 42,5 million passengers (CPB & PBL, 2015). Of these 42.5 million passengers, 26.9 million are expected to be OD-passengers. Based on these passenger volumes and on the calculated potential market shares for APT, HSR and HPT in the different design scenarios (see *Table 23*) it is assessed in which of the HPT design scenario's HPT can potentially deal with the predicted passenger volumes that AAS cannot accommodate for in the situation without HPT (in WLO scenario high). In *Table 24* the passenger volumes for 2050 for each of the modes, in the different scenarios, are given, assuming a total passenger demand of 107.4 million OD passengers. In WLO scenario low 110 million passengers are expected at AAS in 2050, of which 69.5 million are OD passenger.

Table 24: Passenger volumes for the different modes for WLO scenario high (2050) (in million passengers)

HPT design scenarios	Passenger volume APT		Passenger volume HSR		Passenger volume HPT	
	WLO high	WLO low	WLO high	WLO low	WLO high	WLO low
Scenario 1: HPT as the faster HSR	42.0	27.7	19.2	12.4	46.2	29.9
Scenario 2: HPT as sustainable plane	46.2	29.9	21.1	13.7	40.1	26.0
Scenario 3: HPT as completely new system	48.9	31.7	22.4	14.5	36.1	23.4
Scenario 4: HPT as part of the multimodal hub AAS	43.5	28.2	19.9	12.9	44.0	28.5

Based on these passenger volumes for HPT in the different design scenarios, it is expected that HPT can accommodate for those 26.9 million OD-passengers at AAS in all of the design scenarios. Under the assumption that transfer passengers value travelling by means of APT, HSR and HPT in the same way as OD-passengers do, HPT is also expected to be able to facilitate the transport of the transfer passengers present in the surplus. However, it is important to keep in mind when estimating the market size of HPT in terms of passenger volumes, that the predictions made are only valid within the assumptions made in this thesis.

10.2 The role of different stakeholder coalitions in the different design scenarios

In paragraph 10.1 the impact of different design scenarios for HPT on the potential market shares for APT, HSR and HPT was assessed, only taking a traveller perspective into account. However, the design of HPT is situated in a complex socio-technical system in which various stakeholders are involved. Whether or not these stakeholders are willing to form coalitions, makes some design options of HPT more likely to occur than others. Therefore, an assessment is made whether there is either alignment or a disconnect between the HPT design scenarios that are most preferred from a user perspective and the design scenarios that are most likely to occur from a stakeholder perspective. This scenario analysis conducted in paragraph 10.1, together with chapter 4 and the conducted stakeholder interviews (*Appendix D* to *Appendix L*) form the basis for this analysis.

[49] This assumption is based on the fact that in 2017, 63,2% of the passengers at AAS were origin-destination passengers, and 36,9% of the passengers were transfer passengers (KiM, 2018). Assumed is that this deviation among OD-passengers and transfer passengers does not really change of the years.

Scenario 1, HPT as the faster HSR, was found to be the preferred design scenario from a user perspective (43.0%). In this scenario, HPT is located within a 15-minute reach from the city centre of Amsterdam, no security checks are in place and baggage check-in is not possible. In the decision-making regarding the new location, more complex stakeholder dynamics come into play compared to when HPT would be located at AAS. The municipality of Haarlemmermeer, the MRA and the province of Noord-Holland are key players that need to be willing to form a coalition regarding the new location of the HPT station. Diverse interests play a role and complex trade-offs need to be made by the different stakeholders when a new HPT station is built. This is mainly due to the large impact of this on its surroundings and on the environment. Besides that, when an HPT station is built at a new location, it is essential that other modes of transport will be connected to the HPT station as well. Therefore, involvement of ProRail, NS and the regional transport operators is crucial. Nonetheless, these stakeholders are not seen as a potential bottleneck for the HPT design. However, building these connections from the HPT station to the rest of the Dutch transport network enlarges the impact of the HPT station on its surroundings even more, making this scenario even more complex. Creating a new location for the HPT station thus is a complex matter from a stakeholder perspective and makes this design option less likely to happen.

Furthermore, in scenario 1 no security checks are in place and baggage cannot be checked in. No stakeholder coalitions are thus needed regarding these design aspects. To conclude, scenario 1 is thus most preferred from a user perspective, but from a stakeholder perspective, building a new HPT location is complex. There thus seems to be a disconnect between what is most preferred from a user perspective and what expected to be most likely to happen from a stakeholder perspective.

Design scenario 2, HPT as sustainable plane, is the HPT design scenario is ranked third in terms of market share for HPT (37.4%). In this scenario HPT is located at AAS, elaborate security checks are in place and baggage is checked in. AAS will be the main stakeholder involved in locating HTP at AAS. Given that AAS wants to maximize the number of passengers that travel via AAS and want to be able to deal with the passenger demand, they are expected to be willing to facilitate HPT at AAS. Again, also the Municipality of Haarlemmermeer and the Province of Noord-Holland need to be on board, but the construction of HPT at AAS will be of less impact on its surroundings, expecting less resistance from these parties compared to when a new HPT location needs to be built. Besides that, when HPT is located at AAS it is expected to be in more direct competition with APT, potentially leading to less flights from and to AAS. This reduces that air-and noise pollution related to AAS for residents living around AAS and has a positive impact on the willingness of stakeholder to take part in facilitating HPT at AAS. Besides that, the economic advantages related to AAS for the residents of Haarlemmermeer also makes stakeholder more likely to be willing to from a coalition. From a stakeholder perspective, locating HPT at AAS is thus more likely to happen than building a new HPT station at another location. Regarding the station location there thus seems to be a disconnect between the most preferred design from a user perspective and what is most likely from a stakeholder perspective.

Moreover, in scenario 2 an elaborate security check is in place, which is not desirable from a user perspective given that this leads to longer waiting times. Having security checks in place does not require complex stakeholder coalitions, given that only the HPT operator and the HPT facilitator are needed to arrange this matter. During the stakeholder interviews it came forward that having an elaborate security check for HPT is expected to be very unlikely. An HPT design with security check light is expected to be most likely (*Appendix D to Appendix L)*. Also, to arrange baggage check-in, no complex stakeholder coalitions are needed. Stakeholder perspective and user perspective are thus aligned regarding these design aspects.

HPT design scenario 3, HPT as completely new system, is the least preferred scenario from a traveller perspective, with a potential market share of 33.6% for HPT. In this scenario the HPT station is located at a new location, security check light is in place and baggage cannot be checked in. This scenario can be complex due to the new location of the HPT station, as was discussed before. Security check light and having checked-in baggage both do not lead to complicated stakeholder dynamics.

Design scenario 4, HPT as part of the multimodal hub AAS, is the second-best scenario from a user perspective with 40.9% market share for HPT. In this scenario HPT is located at AAS, security check light is in place and baggage is checked in. Since HPT is located at AAS, this scenario is also to be considered likely from a stakeholder perspective. No disconnect between what is likely from a stakeholder perspective and what is preferred from a user perspective is in place in this design scenario regarding the location of HPT. Security check light is in place in this scenario, which does not require complex stakeholder coalitions for the HPT station and is seen as the most likely option for security check from a stakeholder perspective. The same goes for having checked in baggage. When taking the HPT system design into account from both a traveller perspective and from a stakeholder perspective, scenario 4 would be the most likely scenario.

Overall, locating HPT at AAS is more likely to happen from a stakeholder perspective. The travellers' perspective on that matter also depends on how the rest of the HPT system would be designed. In terms of security checks, no security checks or security check light are most preferred from a travellers' perspective. No complex stakeholder coalitions are needed in either of these design options but based on the stakeholder interviews a security check light is expected to be the more likely option for HPT. Lastly, having checked in baggage is preferred from a user perspective and does also not require complex stakeholder coalitions. There thus is alignment between stakeholders and travellers regarding this design aspect.

10.3 Summary

Based on the stakeholder interviews that were conducted, three main design uncertainties for the design of the HPT system were identified. These design uncertainties form the basis for the construction of different HPT design scenarios. The design for HPT was varied in terms of three aspects: the location of the HPT station, whether or not security checks that are in place and the type of checks used, and whether or not baggage can be checked in. Based on these design variables four design scenarios were constructed: HPT as the faster HSR, HPT as sustainable plane, HPT as completely new system and HPT as part of the multimodal hub AAS. For each of the design scenarios the potential market shares for APT, HSR and HPT were assessed. Scenario 1 lead to a potential market share for HPT of 43.0%, scenario 2 led to a potential market share for HPT of 37.4%, scenario 3 led to a potential market share for HPT of 33.6% and in scenario 4 a potential market share for HPT of 40.9% was found.

Also, the impact of changes in the individual design uncertainties, in each of the design scenarios was analysed. Based on this analysis, three main take-aways for the design of HPT came forward. The first take-away is to minimize waiting time. When no security check is in place and when HPT is located at a new location waiting time can be minimized more easily and to a larger extent, when compared to the situation in which HPT is located at AAS or when a form of security checks is in place. Secondly, having checked-in baggage is preferred from a traveller perspective, but if baggage handling becomes too time consuming this advantage could potentially be partly diminished. Lastly, travel costs are crucial in the design of HPT. For HPT to gain a larger market share than APT, travel cost needs to be low. By reducing travel cost for HPT, percentage points of potential market share are mainly taken away from APT and to a smaller extent from HSR.

Furthermore, it was studied whether the expected surplus increase in travel demand of 26.6 million OD passengers at AAS could be dealt with by adding HPT to the transport market. In all four design scenarios it was found that the surplus in travel demand that has been predicted for WLO scenario high can be dealt with.

After analysing the design scenarios for HPT, the stakeholder perspective on these design scenarios was also studied. Aim of doing so was to assess whether there is alignment or disconnect between the design scenario that is most preferred from a traveller perspective and the scenario that is most likely from a stakeholder perspective. In terms of the location of the station a disconnect was found, since a new location is preferred from a user perspective but is considered less likely from a stakeholder perspective. In terms of security checks and baggage handling, there is alignment between the stakeholder perspective and the traveller perspective. No issues are thus expected to occur regarding these two design aspects.

11. Conclusion & discussion

In this chapter first the main findings regarding both of the research objectives are given in paragraph 11.1. For both research objectives the formulated research question and sub-questions will be answered. After that, the wider implications of the findings this thesis will be discussed in paragraph 11.2. In paragraph 11.3 the discussion can be found, followed by the recommendations in paragraph 11.4.

11.1 Main findings and conclusions

Two different research objectives were formulated that this thesis strives to address. The first research objective was to design the system of HPT for long-distance travel within Europe. The impact of different designs scenarios for HPT on travellers' mode choice, trade-offs and market shares was assessed in the transport market with APT, HSR and HPT. Focus was on trips with both origin and destination within Europe, with a travel distance of approximately 500 km. Also, the stakeholders and stakeholder coalitions involved in the different design scenarios and the likelihood of those coalitions to be formed were included in the analysis. By doing so, insights were generated on the question whether the design scenarios that are most preferred from a traveller perspective are also most likely from a stakeholder perspective.

The second research objective was to examine the impact of using images of HPT in the introduction of the SP experiment on found preferences, attitude and drop-out of respondents. The main findings and conclusions regarding the first research objective are discussed in paragraph 11.1.1., followed by the main findings and conclusions for the second research objective in paragraph 11.1.2.

11.1.1 Conclusions research objective 1

The passenger demand at AAS has been growing rapidly over the past years and is expected to continue doing so. It is expected that AAS cannot deal with about a quarter of the passenger demand that has been predicted for 2050 in WLO scenario high (CPB & PBL, 2015). In order to be able to deal with this growing passenger demand, AAS is taking other modes such as HSR or innovative modes such as HPT, into consideration (Raad voor de Leefomgeving en Infrastructuur, 2020; Schiphol Group, 2018b). This led to the following main research question this thesis strives to answer:

How could different design scenarios for hyperloop passenger transport influence traveller's mode choice between, and the transport demand for, air passenger transport, highspeed rail, and hyperloop passenger transport for the future long-distance transport market within Europe at AAS?

In order to do so, a DCM was constructed based on SP data. Seven sub questions were defined and have been answered in this thesis.

1. **What are, according to the main stakeholders, the most important design variables for the design of the HPT system for long-distance travel in Europe?**
   A wide range of stakeholders is involved in the design of the HPT system. In order to gain insights into the main design uncertainties, various stakeholder interviews have been carried out. Based on these stakeholder interviews, three main design uncertainties came forward. The first design uncertainty is the location of the HPT station. This could be either at AAS or at a new location that is located within a 15-min reach from the city centre. The second design uncertainty that came

forward was whether or not, and in what form security checks will be incorporated in the HPT system. Three different options were discussed: no security check at all, a security check light in which technological development plays a key role and an elaborate security check, that is comparable to the current APT system. The third design uncertainty concerns baggage handling and focusses on whether or not baggage check-in should be included in the HPT system. These three uncertainties thus form the most important design variables for the design of the HPT system for long-distance travel within Europe, according to the stakeholders.

2. **Which stakeholders and potential stakeholder coalitions influence the solution space for the design of the HPT system for long-distance travel in Europe at AAS and how likely are these stakeholder coalitions to be formed?**

   The main stakeholders that are involved in the design of the HPT system can be divided into six categories: transport facilitators, transport operators, (inter)national governmental bodies, regional and local governmental bodies, representatives of travellers and others. In each of the found design options, different stakeholders are involved, and different stakeholder coalitions need to be formed. Some stakeholder coalitions are more likely to be formed, making some design options more likely to be implemented than others.

   When HPT would be located at AAS, AAS would be the main facilitator and binding stakeholder. Direct competition would be in place between KLM, NS International and Hardt Hyperloop in terms of passenger volumes, but AAS, KLM and NS International could also benefit from the extra passenger demand that is attracted to AAS due to the introduction of HPT at AAS. Therefore, AAS, KLM and NS International are not expected to form a bottleneck in locating HPT at AAS. The Municipality of Haarlemmermeer, the MRA and the Province of Noord-Holland need to be on board as well in order to realize this design option. The Municipality of Haarlemmermeer, the MRA and the Province of Noord-Holland all want to improve accessibility of the region/municipality but also want to maintain and increase the liveability of the area. When a new HPT location would be built outside AAS, these three stakeholders would also need to form a coalition. However, given the fact that the impact on the landscape is substantially larger when building on a new location, a larger bottleneck in terms of stakeholder coalitions is expected in this design option. From a stakeholder perspective locating HPT at AAS is thus more likely than building a new location for HPT within 15-minute reach from the city centre.

   Regarding the form of security checks, if at all, that will be included in the HPT design, stakeholder dynamics are not expected to form a considerable bottleneck in either one of the design options. The HPT operator and the owner of HPT infrastructure need to form a coalition on this topic but given that these two stakeholders have a very similar goal, to transport as many passengers as possible by means of HPT, no considerable issues are expected. From a stakeholder perspective, none of the design options for security checks is more likely than the other.

   The same goes for the question whether or not baggage check-in should be included in the HPT system, if at all. The same stakeholders are involved as for the different forms of security checks and they have similar goals. Therefore, again no considerable bottleneck in terms of stakeholder coalitions is expected regarding this design aspect.

3. **What are the choice probabilities of respectively APT, HSR and HPT and to what extent do the included attributes determine the preferences of travellers when choosing between APT, HSR and HPT for long-distance travel within Europe?**

In the choice experiment APT was chosen in 29,8% of the choice situations, HSR was chosen in 16,8% of the choice situations and HPT was chosen in 53,3% of the choice situations.

When considering the importance of the different attributes that were varied in the choice experiment in the final panel ML model, it was found that the utility contribution of travel cost is the largest for all three modes. Higher travel costs thus make a transport mode less attractive and were found to be of large importance for travellers when choosing between APT, HSR and HPT for long-distance transport. Keeping ticket prices low is thus important when one wants to make a mode more attractive for long-distance transport in Europe.

For in-vehicle time the large variability among the different modes in terms of the utility contribution of this attribute is striking. For APT a quite substantial utility contribution for in-vehicle time was found, while a quite small and insignificant utility contribution was found for HPT. For HSR a very small, positive and not significant utility contribution was found for in-vehicle time, which is counter-intuitive. No hard conclusions can be based upon that parameter estimate.

Waiting time was only varied in the choice experiment for HPT. It was found that waiting time is the time component for HPT that has the highest negative utility contribution of all the time components. Longer waiting times, e.g. due to security checks or longer walking distances, thus make HPT less attractive for travellers. If one wants to make HPT more attractive, minimizing or shortening waiting time for HPT would thus be wise to focus on.

Furthermore, egress time was included in the choice experiment. Again, substantial differences in terms of the size of the utility contributions between the three modes were found. For APT a negative utility contribution for egress time was found, indicating that if egress time for APT increases, and APT would thus be located further from the final destination, APT becomes less attractive from a travellers' perspective. For HSR and HPT only small and insignificant utility contributions were found, of counter-intuitive direction. Therefore, no hard conclusions can be drawn for egress time for HSR and HPT.

The last attribute that was varied in the choice experiment was having checked-in baggage or not. Positive and relatively large utility contributions were found for all three modes. This indicates that travelling with checked-in baggage increases the utility of travellers compared to travelling without checked-in baggage for all three modes. For APT having checked-in baggage leads to a substantially larger increase in utility than for HSR and HPT. For APT having the option to have checked-in baggage is thus of larger impact on the attractiveness of that mode than for HSR or HPT. This could potentially be explained by the endowment effect(Kahneman & Tversky, 1979; Thaler, 1980) or by the larger number of process steps a traveller has to go through when travelling by means of APT compared to HSR and HPT. Having checked-in baggage has a larger positive impact on the utility of HPT than on the utility of HSR.

4. **What are the utility contributions of the different perceptions towards mode-specific characteristics of HSR and HPT and how do these impact the found preferences?**

Various perceptions towards mode-specific characteristics of HSR and HPT were included in the utility functions of HSR and HPT. The parameter estimates for the perceptions indicate how sensitive the utility of a mode is for the extent to which e.g. HSR is seen as environmentally friendly. Each increase of one point on the semantic scale for environment, thus leads to an increase in utility of HPT of 0.172. The utility of HPT is thus 0.688 utility point higher for a traveller that sees HPT as very environmentally friendly (5), compared to someone that sees HPT as very environmentally unfriendly (1).

When comparing the parameter estimates for HSR and HPT, it should be noted that all the found parameter estimates for the different perceptions are higher for HSR than for HPT. Based on the found utility contributions of the different perceptions for HSR and HPT, it can be observed that the utility of both modes is most sensitive for the extent to which people see HSR and HPT as comfortable. Besides that, the average utility contributions of trip comfort of HSR and HPT are very similar. Seeing HSR or HPT as a comfortable mode to travel with, thus almost has the same contribution to utility and to how attractive travellers see that mode.

Seeing HSR and HPT as more environmentally friendly leads to the second largest increase in utility when comparing the different perceptions. However, a quite substantial difference was found in terms of the average utility contributions of this perception of HSR and HPT. Seeing HSR as more environmentally friendly thus leads to a larger increase in utility than seeing HPT as environmentally friendly does.

Moreover, seeing HSR and HPT as a more frequently departing modes, only leads to a small increase in utility of both modes. For HSR the impact of perceived frequency was found to be substantially larger than for HPT.

For HPT, perceived reliability was found to only influence the utility of HPT, while for HSR a more positive perception regarding reliability was found to be of substantial impact on the attractiveness of HSR. Ensuring that travellers perceive HSR as a reliable mode is thus of more importance for the attractiveness of HSR, than it is for HPT to ensure that travellers see HPT as reliable.

Additionally, the feeling of speed a traveller has, has a larger contribution to utility of HSR than of HPT, but for both modes a quite substantial difference in utility was found between travellers that perceive HSR or HPT to have a higher feeling of speed. However, the perceived feeling of speed is of less impact on the utility of HPT than on the utility of HSR.

Lastly, it was found that seeing HSR as a safe mode leads to slightly larger increase in utility than when a traveller perceives HPT to be equally safe. However, found utility contributions for both modes are quite comparable.

In conclusion, seeing HSR and HPT as more environmentally friendly and more comfortable leads to the largest increase in utility of HSR and HPT. HSR and HPT are seen as being relatively similar in terms of these characteristics. Whether HSR and HPT are seen as frequently departing modes, is only of small impact on utility. This is an interesting outcome given that the high frequency is put forward as one of the unique selling points of HPT. Besides that, the extent to which travellers perceive HSR to be reliable has a quite substantial impact on the attractiveness of HSR, while for HPT reliability only has a very small impact on utility. Lastly, feeling of speed and safety are both only of small influence on the utility of HSR and HPT. Seeing a mode as safer leads to similar increases in utility, when comparing HSR and HPT, while for feeling of speed a larger difference was found between these two modes.

5. **To what extent can heterogeneity in the sample be identified based on socio-demographic factors of respondents and what is the influence of this heterogeneity on found preference and mode choice?**

Business purpose, educational level and income were added to the DCM. In the final panel ML model, it was found that travelling for business purposes has a negative effect on the utility of both

HSR and HPT, compared to travelling for leisure purposes. Leisure travellers thus find HSR and HPT more attractive than business travellers. This effect is found to be larger for HSR than for HPT.

Regarding passenger income it was found that having a higher income has a negative effect on the utility of HSR and has a positive effect on the utility of HPT. People with a higher income thus find HPT more attractive than people with a lower income. However, the parameter estimate for income for HSR was not significant. No further conclusions were thus based upon this parameter.

Lastly, educational level was included in the model. It was found that higher educated people have a higher positive utility of both HSR and HPT than lower educated people. Higher educated people thus find HSR and HPT more attractive than lower educated people and are expected to be more likely to travel by means of HSR and HPT compared to lower educated people.

In conclusion, heterogeneous groups can be identified in the sample. People travelling for leisure purposes, people with a higher income and with a higher educational level are most likely to travel by means of HPT.

6. **To what extent can HPT be (partly) categorized in the nests of air transport or rail transport?**
   In order to determine if HPT is seen as more similar to APT or to HSR by travellers, and thus to what extent HPT could be (party) categorized in the nests of air transport or land transport, additional error components were added to the panel ML base model. One error component was added to both APT and HPT, υ_{air}, and one error component to both HSR and HPT, υ_{land}. For both of the error components, σ was estimated in the ML base model. The value of σ represents the standard error of the error component, and thus represents the variation across individuals in the unobserved factors that are associated with e.g. HSR and HPT.

   σ_{air} was found to be not significant, indicating that APT and HPT are thus not seen as similar in terms of factors that were not varied in the choice experiment (unobserved factors). σ_{land} on the other hand was found to be significant and quite substantial. This large sigma for the land nest in the panel ML base model, means that HPT is seen as more similar to HSR than to APT by travellers. Therefore, HPT is mainly in competition with HSR and is expected to take more market share from HSR than from APT. This is also confirmed by the more similar parameter estimates that were found in the panel ML models for HSR and HPT compared to APT and by comparable perceptions of travellers towards some of the mode-specific characteristics of HSR and HPT.

HPT design scenarios

Based on the design uncertainties that came forward during the stakeholder interviews, four design scenarios for HPT have been constructed: HPT as the faster HSR, HPT as sustainable plane, HPT as completely new system and HPT as part of the multimodal hub AAS. The first scenario (HPT as the faster train) in which HPT is located at a new location, no security checks are in place and baggage cannot be checked in, and the forth scenario (HPT as part of the multimodal hub AAS) in which HPT is located at AAS, security check light is in place and baggage can be checked-in, were found to be the preferred scenarios from a user perspective, leading to the largest potential market share for HPT of respectively 43.0% and 40.9%. However, when considering the HPT as the faster HSR-scenario from a stakeholder perspective, a disconnect comes forward between what is likely to happen from a stakeholder perspective and what is preferred from a travellers' perspective. When locating HPT at a new location, the Municipality of Haarlemmermeer, the Province of Noord-Holland and the MRA need to be on board. An entirely new location for HPT has a substantial impact of its surroundings and the environment, which could lead to complications in terms of stakeholder coalitions that need to be formed. Locating

HPT at AAS is thus more likely to happen from a stakeholder perspective. Which is the case in design scenario 4, HPT as part of multimodal hub AAS, leading to less complicated stakeholder dynamics and making this design scenario thus more likely to happen.

In order to maximize the market share of HPT, three aspects of the design were found to be crucial. Firstly, minimizing waiting time[50] should be focused on. Waiting time is determined by both location of the HPT station and by the form of security that is in place, if at all. When no security checks are in place, this waiting time could be minimized more easily than when security check light or elaborate security checks are chosen. Improvements regarding security check light are largely depending on third parties, due to the technological component, but do provide an opportunity for both ensuring a safe system and at the same time keeping the additional waiting time related to that within limits. However, security light is expected to be the most likely option for HPT.

Secondly, having checked-in baggage when travelling with HPT is preferred from a traveller perspective. However, if baggage handling is poorly organized and leads to an increase in waiting time, the increase in potential market share due to the service of having checked-in baggage is partly diminished by the reduction in market share for HPT due to longer waiting times. Trade-offs thus need to be made regarding this design aspect, which can be a thin line.

Lastly, travel cost is very important in optimizing the potential market share for HPT. Small changes in travel cost are of large impact on the market share of HPT.

11.1.2 Conclusions research objective 2

Including an alternative into an SP experiment that respondents are unfamiliar with, such as a new mode of transport, is a more complex matter than including familiar alternatives, e.g. expanding existing transport alternatives (McFadden, 2017). When unfamiliar alternatives are included in SP experiments, the information with respect to that alternative could influence respondents in their preferences. As a researcher you on the one hand want to inform the respondents, but respondents could take the provided information as clues for desired answers on the other hand (Ben-Akiva et al., 2019). However, little is known about the impact of the way a new mode is introduced in an SP experiment, in terms of text and communication medium used, on choices made by respondents (van Langevelde-van Bergen, 2019). Several studies examine the influence of the communication medium used to provide the information on found preferences, but the effect of using images in the introduction of the SP experiment of preferences, attitudes and drop-out has not yet been studied thoroughly. This led to the following research question this thesis strives to answer:

What is the impact of the way in which HPT is introduced in the stated preference experiment on preferences, attitude and drop-out of respondents?

Drop-out

In order to answer this research question, two different versions of the introduction of HPT were used in the SP experiment that was carried out. Approximately half of the respondents received an introduction with only text, the other half of the respondents received an introduction with both images

[50] Recall: waiting time has been defined as the time that travellers need to wait before or in between the different components of the trip, due to e.g. security checks, checking-in their baggage, walking at the station or the time that travellers arrive at the station/airport before departure of their trip.

and text. 373 respondents opened the survey, of which 56 respondents did not complete the survey. Most respondents dropped out before either the choice tasks or before the perception questions. Only small differences were found in the moment and the number of respondents that dropped-out for both versions of the introduction. These results were also not unambiguous. Therefore, it cannot be concluded that including images in the introduction of the SP has an impact on drop-out of respondents. Using images in the introduction thus did not reduce the number of respondents dropping out during the survey.

Preferences

A parameter was added to the final panel ML model indicating the choice context, β_{images}, referring to the versions of the introduction with both images and text. Only a very small, and not significant, utility contribution for receiving the introduction with both images and text, compared to the text only introduction was found. Therefore, it can be concluded that using images of HPT in the introduction of the choice experiment is thus not of influence on the preferences of respondents and on the found results in this thesis.

Also, the impact of these different versions of the introduction on respondents' understanding of HPT was assessed. A significant difference was found between the group of respondents that received the text only introduction and the group of respondents that received the introduction with both images and text in terms of how clear they experienced the explanation of HPT and of how complete they perceived their image of HPT to be. Respondents that received the version of the introduction with both images and text were found to state that have experiences the explanation as clearer, with a more complete images of HPT as a result.

Furthermore, two questions were included in the survey assessing respondents' knowledge on HPT by means of substantive questions on information provided in the introduction on the specific characteristics of HPT. For both questions, the largest group of respondents answered the questions correctly. However, based on the chi-square test that was performed, it came forward that a significant difference between the group of respondents that received the text only introduction and the group of respondents that received the introduction with both images and text, in how the two substantive questions were answered. Including both images and text in the introduction of the choice experiment thus led to respondents answering the substantive questions more correctly.

Attitude

Lastly, the influence of using images in the introduction of the SP experiment on the perceived similarity of HPT with either APT or HSR was studied. It was found was that people who received the text only introduction do not see HPT as more similar to APT. When considering the model in which HSR and HPT are in the same nest, it was found that HPT is seen as more similar to HSR by people who received the introduction with both images and text compared to people who received the text only introduction. How a certain mode looks thus plays a role in its positioning compared to other modes and its competitive position.

All in all, the drop-out rate did not turn out to be lower among the group of respondents that received the introduction with both images and text. Using images and text in the introduction thus does not reduce drop out of respondents when filling out the survey. Moreover, a significant difference was found between the group of respondents that received the introduction with both images and text and the group of respondents that received the introduction with text only, in terms of how the substantive questions were answered. Lastly, using images in the introduction of the SP experiment does not impact the preferences of respondents. However, respondents that received the introduction with both images and text see HPT as more similar to HSR. Respondents that received the introduction with only text, on the other hand, do not see HPT as more similar to APT.

11.2 Wider implications of this thesis

The results that were found in this thesis have wider implications for policy, for stakeholders and for society. Policy advice can be formulated, mainly applicable for the key stakeholders: the HPT developer (Hardt Hyperloop in this thesis) and the airport operator (AAS in this thesis). When considering the wider implications of the thesis, it should be kept in mind that this thesis solely considers journeys with both origin and destination within Europe, with a distance around 500 kilometres from AAS, and only takes APT, HSR and HPT into consideration.

The results that were found in this thesis show that HPT indeed has the potential to play a role in the future of long-distance transport in Europe and that people state that they are willing to use this new technology for transportation. However, it was found that **HPT is seen as more similar to HSR and thus is more in competition with HSR than with APT**. If the aim of introducing HPT is to merely reduce APT demand, striving for a transport market for long distance transport that is dominated by HPT and HSR, HPT might not be the right mode to facilitate this shift to land based modes. APT remains a popular mode for long distance transport and as long as no policy measures are taken to make APT less attractive, this will continue to be the case. If one wants to resolve current issues at AAS (a too large expected passenger demand compared to the limited availability of the number of flight movements) and at many other airports, policies that make APT less attractive and other modes such as HSR and HPT more attractive have a key role to play.[51] Incorporating the environmental cost of travelling by means of APT in the ticket prices of APT, is a key component for such a policy. This could potentially increase competition for APT and make other modes of transport a more attractive alternative. This is not something that can be done by the Netherlands alone. European cooperation is crucial in APT related policies, in order to maintain fair competition within the European market for air transport.

Moreover, it was found that travellers that see HPT as more **comfortable and more environmentally friendly** find HPT more attractive. From a marketing perspective, the HPT developer should thus focus on making sure that people indeed see HPT in that way. This could lead to an increase in the potential market share of HPT. Additionally, the high **frequency** of HPT is often put forward as one of its main selling points by HPT developers. However, it was found that whether or not travellers perceive HPT to be a frequently departing mode, only has a small influence on the attractiveness of HPT. To bridge this gap between the focus of the HPT developers and the preferences of travellers, two options come forward. Either the marketing of HPT should focus strongly on the high frequency of HPT and, more specifically on making sure that travellers know why this high frequency is really beneficial for them, or HPT developers should redirect their focus to other strong aspects of HPT in their marketing.

Besides that, this research shows that **leisure travellers**, travellers with a **higher income** and travellers with a **higher educational level** find HPT to be more attractive than business travellers, travellers with a lower income and travellers with a lower educational level. The HPT developer should therefore be highly aware of the type of travellers that find HPT an attractive mode of transport. He

[51] This also came forward during the stakeholder interviews (*Appendix D* to *Appendix L*).

could either focus on attracting this first group even more or focus on diversifying its travellers among passengers in the second group. Both strategies require different steps from a marketing perspective.

In terms of the system design of HPT also various recommendations can be given. The first being that the HPT developer should focus on minimizing **waiting time**[52] for HPT, given the large impact of waiting time on the attractiveness of HPT from a travellers' perspective. The time related to security checks and walking at the station/airport should thus be minimized and is important to keep in mind when designing the HPT system. When HPT is located at a new location within 15 min reach from the city centre, walking distances are expected to be shorter and the hyperloop developer itself is mainly in charge of minimizing waiting time. However, when HPT would be located at an airport, minimizing waiting time becomes a more complex matter. Walking distances are longer at the airport and the design of the HPT system depends more on the cooperation with and policies of the airport operator. Longer waiting times lead to a smaller potential market share for HPT which is not desirable for both the HPT developer and airport operator. It is thus important that these two stakeholders are willing to cooperate and strive for minimization of waiting time of HPT at the airport. Not only the HPT developer benefits from a smooth HPT journey but also the airport operator could largely benefit from that.

The second recommendation in terms of system design regards **locating HPT at the airport**. This would increase the number of passengers at the airport, could lead to increased profits for the airport, would strengthen the position of the airport as a multi-modal hub, has less stakeholder complexity is involved and boost the business climate of the area around it. In contrast, not locating HPT at the airport could cause substantially lower passenger demand at the airport, given that HPT passengers would then not travel through the airport, possibly weakening the hub position of that airport. Therefore, the airport operator would be well advised to focus on providing HPT with minimized waiting time at the airport and facilitate the HPT developer regarding this matter.

Furthermore, locating HPT at the airport could have large advantages for the HPT developer, especially when having the future expansion of the HPT network in mind. This is mainly due to the fact that airports are well-connected to the rest of the transport system on land and is also connected to international air transport. The total passenger demand at airports is large and travellers have a lot of travel options at their disposal, which could make travelling by means of HPT more attractive for travellers when HPT is located at an airport.

In this thesis the focus was only on passengers with both origin and destination within Europe. But if the HPT developer and the airport have the ambition to also transport **transfer passengers**, this would be easier to do when HPT is located at the airport, given that a large share of these passengers already travels via the airport, using APT. On the other hand, in order to attract more OD passengers, locating HPT more closely to the city is more logical. HPT developers thus needs to make further trade-offs in whether they want to optimize their system for OD passengers or whether they choose to design the system also taking transfer passengers into account.

Additionally, during the stakeholder interviews several recommendations were made regarding the **current HSR transport system** for long-distance travel. These recommendations appear to be highly relevant for the future of HPT as well. HSR has potential, but in order to gain substantial market share, changes to the current ticketing system and its marketing strategy need to be made. One of the main

[52] Recall: waiting time has been defined as the time that travellers need to wait before or in between the different components of the trip, due to e.g. security checks, checking-in their baggage, walking at the station or the time that travellers arrive at the station/airport before departure of their trip.

issues for HSR that came forward during the stakeholder interviews was the way in which ticketing is organised. Not only the fact that HSR tickets become available only three months in advance was mentioned, but also a lack of alignment and cooperation between HSR operators of different European counties, was put forward. Arranging ticket integration for the different parts of the journey made by means of HSR or made by multiple modes was put forward as way to make HSR more attractive. To resolve this issue, cooperation between train operators and other transport operators is needed on a European level. Currently the necessary European cooperation to resolve this issue is lacking.

In addition to the ticketing issue, the marketing of HSR was raised during the interviews as an area in which there is ample room for improvement. Focus should be on promoting HSR as a very sustainable, very comfortable and very reliable mode of transport. Another question raised during the stakeholder interviews regarding the HSR design was the impact of introducing checked-in baggage handling in HSR. Based on the results of this thesis it is expected that doing so will make HSR more attractive from a user perspective. In conclusion: in order to strengthen the HSR system European cooperation thus needs to be sought regarding ticket integration, marketing of HSR needs to be improved and introducing checked-in baggage in HSR should be reconsidered. Lessons that seem highly relevant for the future of HPT as well. HPT developers are well advised to keep this in mind when designing the HPT system.

11.3 Discussion

Various limitations and points for discussion can be identified for this thesis. These limitations could be of influence on the found results and should therefore be acknowledged. Firstly, it should be noted that the found results in this thesis only apply under the research conditions set in this thesis and one should be careful when interpreting these results. The set research conditions are the following: journeys with both origin and destination within Europe, journey distance around 500 km and a transport market with only APT, HSR and HPT. Besides that, one should be careful with making statements on the potential market size of HPT in terms of passenger volumes, since making these predictions can be tricky to do based on SP data (Fujii & Gärling, 2003).

Moreover, respondents of the choice experiment were asked to make a decision in the far future (2050), on a mode of transport they are not familiar with. HPT was chosen in more than half of the choice situations, which could indicate that respondents have a too positive image of this new mode of transport. This can be caused by the fact that people have not travelled with HPT and thus have no negative travel experiences. Also, the fact that it can be seen as a new, futuristic mode that meets the shortcomings of HSR and HPT, could have played a role. It is assumed that APT and HSR remain the same as they are now, but these modes of transport will also develop over the years. Also, other technological and non-technological developments outside of transport realm could be of impact on travel behavior and mode choice. Also, travel habits could change over the years. All this was not taken into account in this thesis but could potentially be of influence on the outcomes.

Using SP data also leads to a point for discussion, since there always is a hypothetical bias in place when using this type of data. Respondents were asked to make a decision in a hypothetical situation, but it is unknown whether people would have made the same choices in real life (Fifer et al., 2014). Comparing SP and RP data could normally bring useful insight into the extent to which hypothetical bias played a role. However, since HPT does not (yet) exist, this is not an option for this thesis.

Furthermore, some remarks should be made regarding the choice experiment that was used in this thesis. Some of the found parameter estimates for the attributes turned out not to be significant and very small. This could potentially be caused by the novelty effect (Koch et al., 2018). This was the case for both in-vehicle time and egress time for HSR and HPT. One should thus be careful when interpreting conclusions regarding these parameters and should not attach too much value to them. In other studies that applied DCM to assessing long-distance travel behavior, including APT and HSR, larger and significant utility contributions were found for in-vehicle time and egress time (Behrens & Pels, 2012; Terpstra & Lijesen, 2015). The second remark regarding the choice experiment is that, even though the found parameter estimate for versions of the introduction with both images and text was not significant, the possibility remains that respondents could have filled out the choice task differently if they would have received the other version of the introduction.

Two final remarks need to be made. Firstly, in this thesis the hypothetical situation in which HPT would be reality is under study. However, if this will indeed happen, remains unknown. Respondents' view on whether or not it is considered to be realistic for HPT to become reality could have been of impact of made choices. Secondly, respondents were asked to make choices in a situation without the current Corona pandemic. However, the long-term impact of COVID-19 on travel behavior remains uncertain and could be potentially be far reaching, especially in the realm of business travel.

11.4 Recommendations for further research

HPT and the future of long-distance transport is a topic on which still a lot of aspects remain unknown, requiring additional research. Therefore, several suggestions for further research are provided. In this thesis only the modes of APT, HSR and HPT are included in the analysis. In reality there are other modes of transport as well as transport innovations that are or can be of influence on passengers' mode choice for long distance transport. Including conventional car and night train could be an option when looking at existing modes of transport, but also autonomous cars and airplanes using alternative fuels could be interesting innovations to include in further research regarding the potential of HPT and the future of long-distance transport.

Besides that, only journeys of distances around 500 km, with both origin and destination within Europe were taken into consideration in this thesis. This thesis recommends to study how preference and mode choice change with longer journey distances. What would be the implications of that for the design of HPT? Moreover, in this thesis only OD-substitution was studied. Found results do thus not apply for transfer passengers and transfer substitution. Given that a substantial share of passengers at AAS are transfer passengers, this thesis recommends studying the preferences and mode choices of this group of travellers and to assess the impact of these on the system design of HPT.

Furthermore, in this thesis no induced demand due to the introduction of HPT was assumed. Whether the introduction of HPT would generate additional passenger flows is a subject for further study. If HPT would lead to new travel demand, part of the positive environmental effect of HPT as compared to APT is diminished by these additional trips. Moreover, it is not known if these induced passengers make the same trade-offs when choosing between APT, HSR and HPT as the current travellers. Therefore, studying the trade-offs made by these induced travellers when choosing between APT, HSR and HPT, is also recommended. AAS is taking HPT into consideration as a potential mode to reduce the number of flights at AAS. However, it was found that HPT is more in competition with HSR than with APT. With this aim of AAS in mind, it should be studied how the HPT design can be changed in order to increase the degree of competition with APT and reduce its degree of competition with HSR.

Also, this thesis proposes recommendations regarding the choice experiment and the data collection. In the choice experiment HPT was only introduced briefly, but the negative effects and the financial and societal cost as a result of the implementation of HPT were not mentioned. Assessing whether this would impact results is therefore recommended. Another recommendation regarding the choice experiment is to study the impact of the novelty effect on the choice of respondents in more detail. The parameter estimates in this study for in-vehicle time and egress time were found to be not significant, which is potentially caused by the novelty effect. By knowing the impact of the novelty on those parameter estimates, a more accurate view on the impact of in-vehicle time and egress time on mode choice can be gained. In addition, including other attributes, such as frequency and time of day of departure, would be interesting for further research.

In the survey various questions regarding the attributes of respondents towards the different modes were included. These perceptions were only measured by asking one question for each perception. Assessing the perceptions based on multiple questions per perception could provide a more in-depth measurement of these perceptions. Doing so would be interesting for further research. Besides that, this thesis has chosen AAS as central point of study and as the location of departure for all three modes. However, most people already have an experience and perceptions regarding travelling at AAS. This also can have been of influence on their preferences and mode choice. The perceptions towards travelling at AAS have not been studied, but it could be interesting to study to what extent these perceptions influence the given responses.

Moreover, data collection in this thesis took place by means of an online panel of respondents, leading to 305 respondents. Using a panel is a very practical way of collecting data but could also cause a bias. The respondents that completed the survey got a reward afterwards, which could have caused people to click through the survey without actually reading the questions. In the data cleaning process, some respondents were excluded due to too short response time, but this threshold was set relatively low. The fact that a reward is given for completing the survey also attracts a certain type of people to become part of a panel. These are expected to be mainly people with enough free time to participate in various surveys and people that can use some extra money. Therefore, it is recommended to study whether working with a larger group of respondents that was not merely recruited by means of an online panel and did not receive a reward for filling in the survey, leads to different results than those found in this study.

The design scenarios and the impact of the market shares for APT, HSR and HPT were studied based on the MNL model. This model does not take into account that HPT and HSR are seen as more similar and are therefore more in competition with each other. It is recommended to study the potential market share of HPT in the different design scenarios by means of the panel ML model, that does postulate the perceived similarity between HSR and HPT. Another recommendation for further research regarding the design scenarios can be made. In this thesis changes were only made to the HPT alternative. It is very likely that the alternatives of APT and HSR will also change over time. The impact of changes in e.g. price or in-vehicle time for either APT or HSR on the potential market share of HPT has not been studied. Therefore, it is recommended to do so, given that this will provide a more realistic representation of the transport market with APT, HSR and HPT. Studying whether or not a difference in outcomes can be found when using the ML model, can also be recommended for further research.

Due to the use of the MNL model to study the impact of the different design scenarios of HPT, linearity is assumed. However, a reduction in e.g. travel cost will not endlessly lead to an increase in the potential market share for HPT. It is to be expected that a saturation point will be reached, indicating a limit to which a reduction in e.g. travel cost will continue to lead to increases in potential market share. When this saturation point is reached for travel cost, in-vehicle time, egress time and waiting time should be studied. This would provide more insight into the limits within which the HPT design could be optimized.

Regarding the influence of the way in which unfamiliar alternatives are introduced in the introduction of an SP experiment, three recommendations can be made. First of all, in this thesis quite small groups of respondents completed the survey for each version of the introduction. It could be studied whether more respondents for each version of the introduction would lead to different results. Secondly, only a distinction between a version of the introduction with only text and a version with both images and text is made in this thesis. More variation in the introduction could be made, for example using virtual reality as well. Thirdly, the use of images did not reduce the drop-out of respondents. Looking into other ways that could reduce the drop-out rate of respondents in SP experiments is therefore recommended.

Lastly, it could be assessed whether preferences for certain types of introductions, using different types of media are preferred by specific groups or for specific research objectives. By knowing that some groups have certain preference regarding information provision, researchers could fit their survey to the preferences of their targeted group of people.

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Appendix

Appendix A – Methodology of literature review research objective 1

The database of Scopus was used to find scientific literature. From the found articles, both forward- and backwards snowballing was applied to enlarge the found body of literature. The literature search was conducted using the following keywords or combinations of these keywords: *hyperloop, evacuated tube transport, emissions, air transport, highspeed rail, flight substitution, policy, acceptance, user perception, choice modelling, preferences, transport market.* The found articles were analysed and subsequently categorized based on their key concepts. Since hyperloop is a relatively new technology, being developed and research all around the world (Gkoumas & Christou, 2020a), no selection in geographical area under study was made. Only English sources were included, whereas articles published before 2010 were excluded.

Based on the inclusion criteria, 49 articles were selected by considering title, abstract and keywords. After more thorough selection 20 articles were included in the literature review. Two key concepts were derived from the included articles: transport market and mode-choice and trade-offs. *Table* 24 provides an overview of the included articles and the key concepts covered by the articles.

Table 25: Overview of scientific articles included in literature review for research objective 1

Authors	Title	Year of publication	Key concepts
D'Alphonso, Jiang, Bracaglia	Air transport and high-speed rail competition: Environmental implications and mitigation strategies	2016	Transport market
Behrens & Pels	Intermodal competition in the London-Paris passenger market: High-Speed Rail and air transport	2012	Transport market & mode-choice and trade-offs
Bergantino & Madio	Intermodal competition and substitution. HSR *versus* air transport. Understanding the socio-economic determinants in mode choice	2020	Mode choice & trade-offs
Chiambaretto & Decker	Air-rail intermodal agreements: Balancing the competition and environmental effects	2012	Transport market
Decker et al.	Conceptual feasibility study of the hyperloop vehicle for next-generation transport	2018	Transport market
Dobruszkes et al.	Does European high-speed rail affect the current level of air services? An EU-wide analysis	2014	Transport market & mode-choice and trade-offs
Gkoumas &Christou	A Triple-Helix Approach for the Assessment of Hyperloop Potential in Europe	2020	Transport market & mode-choice and trade-offs
van Goeverder, Janic, et al.	Is hyperloop helpful in relieving the environmental burden of long-distance travel? An explorative analysis for Europe	2018	Transport market
van Goeverden, Milakis, et al.	Analysis and modelling of performances of the HL (hyperloop) transport system	2018	Transport market
Hansen	Hyperloop transport technology assessment and system analysis	2020	Transport market
Janic	Future advanced long-haul Evacuated Tube Transport (EET) system operated by TransRapid Maglev (TRM): a multidimensional examination of performance	2019	Transport market
Janic	Estimation of direct energy consumption and CO2 emissions by high speed rail, trans rapid maglev and hyperloop passenger transport system	2020	Transport market
Kroes & Savelberg	Substitution from Air to High-Speed Rail: The Case of Amsterdam Airport	2019	Transport market & mode-choice and trade-offs

Nash	When to invest in High Speed Rail	2013	Transport market
Rajendran & Harper	A simulation-based approach to provide insights on Hyperloop network operations	2020	Transport market & mode-choice and trade-offs
Román & Martín	Integration of HSR and air transport: Understanding passengers' preferences	2014	Mode choice & trade-offs
Takebayashi	Air transport and high-speed rail competition: Environmental implications and mitigation strategies	2014	Transport market
Terpstra & Lijesen	The impact of highspeed rail on airport competition	2015	Transport market & mode-choice and trade-offs
Voltes-Dorta & Becker	The potential short-term impact of a Hyperloop service between San Francisco and Los Angeles on airport competition in California	2018	Transport market & mode-choice and trade-offs

Appendix B – Methodology of literature review research objective 2

The database of Scopus was used to find scientific literature. From the found articles, both forward- and backwards snowballing was applied to enlarge the found body of literature. The literature search was conducted using the following keywords or combinations of these keywords: Stated preference experiment, Stated choice experiment, non-existing alternatives choice experiments, conjoint analysis, attitude framing discrete choice modelling, framing in decision-making, information formats stated choice experiment, text-only discrete choice model, video/ image use stated choice. The found articles were analysed and subsequently categorized based on their key concepts. Only English articles were included, and no selection was made based on year of publication.

Based on the inclusion criteria, 37 articles were selected by considering title, abstract and keywords. After more thorough selection 18 articles were included in the literature review. Two key concepts were derived from the included articles: influence of provided information and communication medium used. *Table 25* provides an overview of the included articles and the key concepts covered by the articles.

Table 26: Overview of scientific articles included in literature review for research objective 2

Authors	Title	Year of publication	Key concepts
Arellana, Garzón, Estrada & Cantillo	On the use of virtual immersive reality for discrete choice experiments to modelling pedestrian behaviour	2020	Communication medium used
Ben-Akiva, McFadden & Train	Foundations of stated preference elicitation: Consumer Behavior and Choice-based Conjoint Analysis	2019	Impact of provided information
Hoehn, Lupi & Kaplowitz	Stated choice experiments with complex ecosystem changes: The effect of information formats on estimated variances and choice parameters	2010	Communication medium used
Howard & Salkeld	Does attribute framing in discrete choice experiments influence willingness to pay? Results from a discrete choice experiment in screening for colorectal cancer	2009	Communication medium used
Kragt & Bennett	Attribute Framing in Choice Experiments: How Do Attribute Level Descriptions Affect Value Estimates?	2012	Impact of provided information
Van Langevelde- van Bergen	Public support for Tradable Peak Credits as an instrument to reduce congestion - A stated choice experiment that is simultaneously used to investigate the influence of content and medium of stated choice introductions	2019	Impact of provided information, Communication medium used
Mazoor, Molins & Serrano	Interoception moderates the relation between alexithymia and risky-choices in a framing task: A proposal of two-stage model of decision-making	2021	Communication medium used
McFadden	Stated preference methods and their applicability to environmental use and non-use valuations	2017	Impact of provided information
Molin	Causal analysis of hydrogen acceptance	2005	Impact of provided information
Özdemir, Johnson &Hauber	Hypothetical bias, cheap talk, and stated willingness to pay for health care	2009	Impact of provided information
Patterson, Darbani, Rezaei, Zacharias & Yazdizadeh	Comparing text-only and virtual reality discrete choice experiments of neighbourhood choice	2017	Impact of communication medium used
Raux, Chevalier, Bougna & Hilton	Mobility choices and climate change: Assessing the effects of social norms, emissions information and economic incentives	2020	Impact of provided information

Rossetti & Hurtubia	An assessment of the ecological validity of immersive videos in stated preference surveys	2020	Communication medium used
Sandorf	Did You Miss Something? Inattentive Respondents in Discrete Choice Experiments	2019	Communication medium used
Sugden	Anomalies and stated preference techniques: A framework for a discussion of coping strategies	2005	Impact of provided information
Tortolini, Degrati & Coscarella	Framing and communicating southern right whale – kelp gull biological interaction in Peninsula Valdés, Argentina: The effects of attribute frames on human's perceptions and decision-making policies	2021	Impact of provided information
de Vries	How Positive Framing May Fuel Opposition to Low-Carbon Technologies: The Boomerang Model	2017	Impact of provided information
Wu, Swait & Chen	Feature-based attributes and the roles of consumers' perception bias and inference in choice	2019	Impact of provided information

Appendix C - Interview protocol

Note: Om de vragen zo duidelijk mogen te formuleren voor de geïnterviewde en verwarring te voorkomen, is gekozen om het woord aspecten te gebruikten waar in vaktaal attributen gebuikt zou zijn.

Algemene gegevens

Naam geïnterviewde:
Organisatie:
Datum:

Deel 1 – Algemene vragen

Q1.1: *Hoe is uw organisatie betrokken bij het vormgeven van de transportmarkt voor lange aftands transport van de toekomst?*

Q1.2: *Wat is uw persoonlijke rol op dit gebied?*

Deel 2- Ontwerp vragen

Q2.1: *Beschouwd u hogesnelheidstrein als mogelijk alternatief om korte afstandsvluchten vanaf Schiphol te substitueren?*

- De prijs van rail blijft belangrijk, op rail zit nu een accijns die op vliegen niet zit.
- Wat is er nodig om een substitutie van korte afstandsvluchten door HSR te realiseren?
- Hoe komt dit systeem er volgens u waarschijnlijk uit te zien?
    - Welke ontwerp aspecten staan al vast? (bijv schiphol, waar komen stations?)
    - Zijn er al concrete plannen voor de inrichting van Schiphol om hogesnelheidstrein te faciliteren?
        - Is Schiphol de beste plek om deze hub voor lange afstandsreizen te creëren?
        - Wordt dit bijv het huidige NS-station voor NS?
    - Wat zijn volgens u de belangrijkste ontwerp elementen om substitutie van korte afstandsvluchten door hogesnelheidstrein en hyperloop plaats te laten vinden?
        - Locatie stations – gemak van overstap
        - Vervoer tussen de stations van de verschillende modaliteiten indien nodig
        - Integrale tickets (boek je alles in een keer?)
        - Douanecontrole
        - Bagage door labeling of niet?
        - Boek je een specifieke reis voor HPT en HSR of zoals nu met normale trein?
        - Frequentie HPT en HSR?

- *Wat is denkt u de belangrijkste reden waarom hogesnelheidstrein nu nog steeds relatief weinig wordt gebruikt voor lange afstandstransport binnen Europa?*
    - Wat zijn aspecten die dit kunnen blokkeren?

Q2.2: *Beschouwd u hyperloop als mogelijk alternatief om korte afstandsvluchten vanaf Schiphol te substitueren?*

- Denkt u dat hyperloop realiteit gaat worden? Waarom wel/niet?
- Wat is er nodig om een substitutie van korte afstandsvluchten door hyperloop te realiseren?

- Hoe komt dit systeem van hyperloop er volgens u waarschijnlijk uit te zien, als het geïmplementeerd gaat worden?
    - Wat ontwerp aspecten staan al vast? (bijv Schiphol, waar komen stations?)
    - Zijn er al concrete plannen voor de inrichting van Schiphol om hyperloop te faciliteren?
        - Is Schiphol de beste plek om deze hub voor lange afstandsreizen te creëren?
        - Wordt dit bijv het huidige NS-station? Verder van Schiphol af?

Q2.3: *Hoe gaat een transport system voor lange afstand transport met luchtvaart, hyperloop en hogesnelheidstrein er volgens u uitzien?*

- Wat zijn volgens u de belangrijkste ontwerp elementen om substitutie van korte afstandsvluchten door hogesnelheidstrein en hyperloop plaats te laten vinden?
    - Mate van integratie van de systemen
    - Locatie stations – gemak van overstap
    - Vervoer tussen de stations van de verschillende modaliteiten indien nodig
    - Integrale tickets (boek je alles in een keer?)
    - Douanecontrole
    - Bagage door labeling of niet?
    - Boek je een specifieke reis voor HPT en HSR of zoals nu met normale trein?
    - Frequentie HPT en HSR?
- Zijn er al concrete plannen voor de inrichting van Schiphol om hyperloop en hogesnelheidstrein te faciliteren?

Q3.3: *Waar zitten voor uw organisatie de grootste onzekerheden met betrekking tot het ontwerp?*

- *Waar zou u graag meer inzichten in willen krijgen?*

Deel 3 – Stakeholder coalities

Q3.1: *Wat zijn de belangrijkste partijen betrokken bij het ontwerp van het transportsysteem van de toekomst, waarin luchtvaart, hogesnelheidstrein en hyperloop worden meegenomen?*

- Wat zijn de belangrijkste partijen voor hogesnelheidstrein?
- Wat zijn de belangrijkste partijen voor hyperloop?
- Wat zijn de belangrijkste partijen voor luchtvaart?

Q3.2: *Wat zijn de belangrijkste partijen waarmee uw organisatie samenwerkt?*

Q3.3: *Wat zijn coalities van betrokken partijen die zijn volgens u het meest waarschijnlijk zijn om gevormd te worden?*

- Zijn deze coalities cruciaal om tot een succesvol ontwerp te komen?
- Welke coalities zijn cruciaal?
- Welke coalities gaan nooit gevormd worden?
    - Hoe beïnvloedt dit mogelijk het ontwerp?

Q3.4: *Wat is de invloed van het al dan niet vormen van bepaalde coalities op hoe het ontwerp eruit komt te zien?*

Deel 4 – Design aspecten – Reizigers perspectief

Q4.1: *Wat zijn volgens u de vijf belangrijkste aspecten vanuit de reiziger voor het kiezen van een modaliteit voor lange aftands transport?*

- Zou u de 5 benoemde aspecten van een transport modaliteit kunnen rangschikken van meest belangrijk naar minst belangrijk?

" Op basis van literatuur heb ik een lijst met aspecten opgesteld die in vergelijkbare studies zijn gebruikt, meestal voor het kijken naar de substitutie van korte afstandsvluchten door hogesnelheidstrein. Graag zou ik die even door willen lopen met u."

Doornemen van de lijst met attributen. Per aspect de volgende vragen stellen.

Q4.2: Denkt u dat dit aspect ook van belang is voor reizigers in het kiezen voor een modaliteit?

- Waarom wel/niet?
- Indien ja: waar in de eerder gemaakte rangschikking zou u dit aspect plaatsen?

Q4.3: *Wat zijn denkt u de belangrijkste determinanten voor reiscomfort?*

Attribuut lijst:

- Reistijd
- Tijd van voor-en na transport
- Wachttijd
- Reiskosten
- (Service)Frequentie
- Comfort
    - Reiscomfort van het voertuig
        - Stoelen
        - Beenruimte
        - Faciliteiten (eten, toiletten)
        - Wifi
    - Comfort op stations of vliegvelden
    - Boeken van een ticket (gemak van boeken, manier van betalen, tijd tussen boeking en reis)
    - Mogelijkheid om andere dingen te doen tijdens de reis
- Gevoel van veiligheid
- Betrouwbaarheid van de service (hoeveelheid vertragingen of voertuigen die uitvallen)

Appendix D – Interview Schiphol

Naam geïnterviewde: Jonathan de Bruijne & Klaas Boersma
Organisatie: Schiphol Group
Datum: 17 februari 2021

Ontwerp

- HSR en HPT zijn mogelijke alternatieven om te substitueren tot ongeveer 700 km. Die afstand vooral bepaald door snelheid van HSR. Voor hyperloop ongeveer tot 1250 km.
- Wil een goed concurrerend systeem tussen creëren binnen Europa op internationaal niveau. Wil Global-city region hebben om goed te kunnen concurreren op internationaal en globaal niveau. Ander argument waarom HSR en HPT mogelijk zouden kunnen zijn. Kan ook bijdragen aan de economische competitiviteit van Europa als regio. Steden kunnen steeds meer van elkaar gaan profiteren en daardoor een sterker geheel worden.
- Of van luchthaven naar luchthaven wil blijven gaan is de vraag. Mensen willen uiteindelijk in de stad zijn. Maar kan ook voordeel zijn om al land alle modaliteiten te concentreren. Daar kan ook voordeel worden gehaald. Waarom bijv in Nederland op zowel Amsterdam-Zuid, Schiphol en Rotterdam Centraal willen. Is in Londen een metro ritje en wij maken daar 3 internationale treinstations van. I&W en Metropool regio's hierin belangrijke rol
- Schiphol zegt om substitutie te laten plaats vinden, dan moeten er een directe link zijn op Schiphol. Geldt vooral voor tranfer substitutie, maar voor OD-substitutie wel. Als je knooppunt hebt wil je juist dat je vanaf daar met fijnmazigere infrastructuur naar het stadscentrum doen.
- Laatste stuk naar stadscentrum kan je beter met een andere modaliteit dan hyperloop doen.
- Geen Airport-to-Airport systeem maar hub-to-hub system waarbij de hubs heel goed verbonden zijn met de steden/eindbestemmingen.
- Integratie tussen steden en hubs maakt het een compleet systeem met meerwaarde.
- Amsterdam-Parijs lastige corridor. Heel weinig destination-destination verkeer, vooral als transfer. OD verkeer al vooral met auto en HSR. Is een traject met twee Sky-team partners en twee grote luchthavens is dat traject vooral OD. Anders dan anders corridor, Londen en München interessante
- Allianties OneWorld, Starline and Sky-team belangrijkste luchtvaartallianties.
- Wil dat alle modaliteiten helemaal worden geïntegreerd. Google zou hier bijv best iets mee kunnen doen.
- Zou OV-chipkaart ook veel breder kunnen trekken op het gebied van ticketintegratie. Zitten wel veel haken en ogen aan om dat internationaal voor elkaar te krijgen.
- Wil koffer transport ook integreren. Hoe meer integratie hoe beter. KLM draagt dit ook aan. Wordt gekeken naar OD-bagage transport met NS, KLM en Schiphol.
- Meningen zijn verdeeld over of hyperloop een vliegtuig of trein gaat worden op gebied van bagage. Hangt van de reiziger af. Voor transfer reizigers wil je dat bagage zo is als vliegtuig, maar bij OD-substitutie maakt dat stuk minder uit.
- Hyperloop heeft tijdens de reis rolkoffer formaat, maar wel ook optie om grote koffers in te checken zoals bij vliegen.
- Security checks zullen zeker ook bij HSR en HPT komen gezien de huidige veiligheidsmaatregelen. Groot verschil tussen HSR en HPT ten opzichte van APT is dat je niet van de rails af kan en dus minder terrorisme gevoelig misschien. Zal altijd een vorm van security hebben.

- Bij nieuwe modaliteiten wordt security waarschijnlijk zo streng als bij luchtvaart ingericht. Impliciet wordt daar de vergelijking gemaakt en die veiligheidseisen worden door de reizigers dus ook gesteld. Tijd die je van tevoren aanwezig moet zijn bij HPT en HSR moet dan dus ook langer worden dan op dit moment. Weet niet hoe dit er over 20/30 jaar uitziet, maar ongetwijfeld sneller dan nu.
- Ook health checks gaan zeker een rol spelen ook. Gaat er grote kans komen. Heeft ook impact op de processen. Wat is de invloed van corona op vervoersbewegingen
- Early adopters willen meer betalen, maar daalt ook weer snel. Over 30 jaar hele andere generatie. Gaat meer over hoe mensen om gaan met technologie etc.

Stakeholders

- Ook interessant om te gaan kijken naar het perspectief van EasyJet, Ryanair en Vueling erin staan. Hun businessmodel komt aanzienlijk meer in gevaar dan bijv KLM. Moeten ook worden opgenomen in stakeholder analyse.
- Bij HSR grote barrière door de verschillende operators van de treinen per land.
- Europese samenwerking van belang, bijvoorbeeld ook de ProRails van elk land. Die hebben wel samenwerkingsverbanden op Europees niveau. Zijn al vracht corridors. Voor passagiers transport nu nog heel ingewikkeld en niet goed afgestemd.
- Kracht van hyperloop kan zijn dat het een losstaand systeem is zonder al nationale partijen die er belangen hebben en geen blokkade van bijvoorbeeld lokale treinen. Hyperloop is echt een internationale venture.
- EU is wel waar je moet starten. Hebt EU-commitment nodig om de regelgeving te creëren. Iedereen moet meewerken. Nederlandse invloed stopt bij landsgrenzen. EU wel ook heel log, maar cruciaal.
- Wordt gekeken naar OD-bagage transport met NS, KLM en Schiphol.
- Schiphol werkt vooral samen met NS, ProRail, KLM, NS international (eurostar en Thalys), de overheden dus I&W en EZ&K en de universiteiten, Ook het KiM en de gemeenten om Schiphol, Haarlemmermeer en Amsterdam.
- Met Rijksoverheid wordt samengewerkt, maar de samenwerking naar Europees niveau is nog te dun. Als je substitutie echt wil laten plaats vinden moet je een eerlijke prijs voor vliegen maken, dat is nu niet zo. Dan komt er marktwerking op het spoor. De echte shift naar HSR gaat pas plaats vinden als je Europa erbij trekt

Attributen

- Belangrijkste attributen bij uitstek tijdswinst en ticketprijs. Daarna komt comfort bijvoorbeeld het fijn te vinden om met KLM te vliegen. Speelt ook mee wie betaald. Zekerheid en betrouwbaarheid van de reis ook belangrijk. Wil weten dat er geen vertragingen zijn. Bepaald ook betalingsbereidheid. Misschien onderdeel van comfort.
- Moment van boeken speelt geen rol. Kan altijd nog wel als je echt wil, gaat alleen gepaard met een prijs die je er wel of niet voor over kan hebben. Verder geen issue.
- Afweging wordt altijd vanuit geld gemaakt, comfort komt er meer een beetje bij.
- Trein prijs nu op instaptarief en dan km vergoeding. Bij APT heel anders, gebaseerd op duur van tevoren dat je boek. HPT nu uitgegaan van trein concept. Nu 15 cent per passagier per km. Vergelijkbaar met de trein gehouden.

- Als comfort en ervaring zo veel beter en gaver wordt willen mensen snel meer betalen. Hangt ook sterk samen met nieuwigheid van HPT. Prijs gaat ook heel snel naar beneden.
- Als je substitutie echt wil laten plaats vinden moet je een eerlijke prijs voor vliegen maken, dat is nu niet zo

Appendix E – Interview NS International

Naam geïnterviewde: Tim Geraedts
Organisatie: NS interantional
Datum: 16 februari 2021

Ontwerp

- Business development NS International, bezig met langere termijnstrategie
- Moet het zo makkelijk mogelijk maken voor de reiziger binnen het lange afstandsdomein. Ticketing is hier een goed voorbeeld van
- Belangrijk om het onderscheid te maken tussen OD-substitutie en transfer substitutie. Jij focust op OD-substitutie, dan is Schiphol geen logische aanname. De kracht van HSR is juist dat het een drempelloos systeem is naar de eindbestemming. Schiphol ligt dan veel minder centraal. Als je focust op transfer substitutie, dan is Schiphol wel logisch.
- Als focus niet op city-to-city system ligt wordt het maar een tijdelijke oplossing om minder te vliegen, totdat luchtvaart dan meer duurzaam wordt.
- Het feit dat je je bagage gedurende de hele reis bij je hebt is het voordeel van de trein en evt ook van hyperloop.
- Douanecontroles worden overwogen, maar niet in dezelfde mate als bij vliegen. Zou eerder check-light krijgen wat nu ook in Spanje is bij AVE netwerk. Overwegen wel ander soort controles als gezondheidscontrole. Zou eventueel kunnen blijven en kijken dan ook naar verschillende scenario's hiervoor.
- Europese spoorsector is met ticketintegratie bezig. Dit is een complex proces door de verwevenheid van overheid en vervoerders en dan ook nog verschillende landen. Een centraal platform voor tickets is complex doordat prijs van nationale vervoerders door overheden zijn gereguleerd, maar als de tickets door iemand anders worden verkocht, willen nationale vervoerders wel winst maken. Ook is integrale ticketing complex doordat iedereen met andere systemen werkt. Worden veel verschillende tickiting systemen gebruikt, waardoor tickets onvindbaar zijn in andere systemen. Dat is de grootste bottleneck om integrale ticketing te kunnen realiseren. Op het gebied van boeken en bij de prijzen wordt het dus ingewikkeld
- Lastige door COVID nu ook dat er hele grote verliezen worden gemaakt bij alle vervoerders, maar je moet toch ook blijven investeren om te kunnen groeien.
- Internationaal treinverkeer ook complex door verschillen in beveiligings-en spanningssystemen tussen de landen. Hebt multi-courant materieel nodig, wat zwaarder is en duurder is. Heeft ook weer consequenties voor spoor.
- Om HSR en hyperloop met luchtvaart mee te laten doen moeten eerst verbindingen worden geschaald.
- Ticketprijs ontwikkeling wordt door verschillende dingen beinvloed. In de toekomst zal prijs van HSR dalen omdat je schaaleffecten krijgt, de kosten per stoel zullen dan dus dalen. Externaliteiten worden bij trein nu geïnternaliseerd, dat is bij luchtvaart nog niet het geval. Pas als dat gebeurt krijg je eerlijke concurrentie. Heffingen moeten eerlijk worden en evenredig naar hoe belastend een modaliteit is. Om de modaliteiten goed te kunnen vergelijken moeten overal eerst de externaliteiten worden meegenomen.

Stakeholders

- NS heeft maar een beperkte hoeveelheid eigen materiaal, waardoor partnerships heel erg belangrijk zijn. Eurostar en DB hebben dat bijvoorbeeld wel
- Internationale partnerships kunnen voordelen bieden op twee manieren: het wordt makkelijker om van en naar Nederland te reizen en de verbindingen binnen Nederland worden beter.
- Focus ligt nu vooral op IC Berlijn, hoewel dat niet om grote reizigersaantallen gaat. Wil de verbindingen leggen met zo veel mogelijk passagiers. Dit traject niet rendabel genoeg.
- 1 dominante as tussen Nederland en het Roergebied waar het IC-netwerk van Duitsland goed op is aangesloten is rendabeler.
- NS en ProRail maken samen lange termijn visies, ook voor kortere termijn. Zijn netwerk visies voor 2030, 2040, 2050. ProRail is de belangrijkste adviseur van I&W op het gebied van infrastructuur investeringen. I&W wil marktvraag maximaal honoreren. Wordt ook sterk gekeken dan hoe NS dat zou kunnen doen.

Attributes

- Bij de Thalys is comfort belangrijk, wordt nu weer verder gemoderniseerd. Probleem bij de Thalys is vooral het gebrek aan capaciteit om de frequenties verder te verhogen. Willen frequentie verhogen naar 12 keer per dag, het liefst zelfs 16 keer per dag.
- Kosten blijven het belangrijkste, moet wel de kosten voor de gehele reis meenemen.

Appendix F – Interview KLM

Naam geïnterviewde: Olivier Oudgeest en Rinze Nieuwhof

Organisatie: KLM

Datum: 10 februari 2020

Ontwerp

- Met HSR kan je bestemmingen tot 500 km aandoen, daarna wordt de reistijd te lang. Als de tijd te lang wordt kan je naar hogere snelheid kijken, waar hyperloop er dus bij komt voor afstanden tot 750-1000 km.
- De kracht van vliegen is dat het los staat van een netwerk en dat je er dus de zee en oceaan mee kan oversteken. Dat is een kracht die je niet snel met hyperloop gaat krijgen. Het vliegtuig heeft wel ook als nadeel dat het volledig van fossielen brandstoffen afhankelijk. Groene brandstoffen helpen absoluut, maar elektrisch vliegen nog echt ver weg dus hebt voor lange afstand synthetische of groene brandstof nodig. Voor lange aftand is hyperloop een hele moeilijke, vliegen zal daar zeker blijven.
- Op kortere afstanden krijg je zeker ook alternatieven voor zoals HPT en HSR, waarbij HSR ook alleen werkt op bestemmingen met een hoge vervoersvraag. Geldt ook voor HPT. Het unieke van kleine vliegtuigen is dat je op rendabele manier ook steden met minder vervoersvraag kan aandoen. HRS veel te hoge capaciteit, krijg je alleen bij hele hoge vervoersvraag vol. Zodra er elektrisch vliegen is voor kleine vliegtuigen en korte afstanden, dan wordt de druk om die korte vluchten te vervangen. Kleinere locaties blijf je dus vliegend doen. Nadelen van HRS en HPT blijven de hoge kosten voor de infrastructuur en de hoge kosten voor de operatie. Moet veel stoelen vullen om het rendabel te maken.
- Bij HPT fijnmaziger maken gaat niet lukken, is het juist heel grofmazig. Kosten van infrastructuur voor fijnmazig netwerk is veel te hoog, gaat commercieel zeker niet lukken en ook met veel subsidie gaat dat bedrijf niet rondkomen. Moet bij HPT echt richten op dikke vervoersstromen. Focus echt op stad naar stad of stad naar luchthaven. Daar liggen zeker nog hele grote uitdagingen waarvan de grootste is om de infrastructuur te bekostigen. Moet vooral gaan zitten op routes met heel veel vervoersvraag.
- Of locatie van stations ertoe doet hangt heel erg vanaf wat de totale reistijd is, maar als nu het alternatief is dat je makkelijk overstapt en max 45 min overstaptijd hebt, ontkom je er voor hyperloop en HSR niet aan om ook op de luchthaven te stoppen. Voorwaardelijk dat hij op de luchthaven stopt en er niet te veel overstaptijd ontstaat. Dan kiezen mensen niet voor dat alternatief.
- Alles wat reistijd toe laat nemen is een blokkade. Bagage moet dan dus ook door gelabeld worden en niet voor extra tijd zorgen. Als je bijvoorbeeld naar Parijs of Londen kijkt moet je al met een treintje tussen terminals reizen, er zijn mensen die dat al een te grote stap vinden. Zelfs op dezelfde luchthaven. Als het voor HPT en HSR nog langer wordt, loop je het risico dat mensen toch voor andere luchthavens blijven kiezen in plaats van voor Schiphol.
- Op Schiphol is er zeker plek voor HPT en HRS te maken, is zeker niet makkelijk want is hartstikke druk op Schiphol, maar als het moet is er zeker ruimte te maken. Locatie is het probleem niet. De vraag hoe levensvatbaar hyperloop is, is eerder de vraag dan of er wel genoeg plek is. Die plek is altijd te creëren.
- Een van de voordelen van de trein is nu dat je niet door een security poortje heen hoeft, dat scheelt veel. Maar als je de overstap van HPT naar vliegen zo soepel mogelijk wil later verlopen

is het misschien goed als je die security check wel al gehad hebt, voor je hyperloop in gaat en op luchthaven in secured area aan kan komen.

- Bij HPT-ontwerp blijft de vraag of het meer een vliegtuig is of meer een trein. Dit heeft ook grote invloed op hoe je het systeem inricht zoals bijvoorbeeld de security. Die dualiteit blijft ook.
- City- to- city zeker voordeel van HSR en HPT. Is zeker winst.
- Integratie tussen de modaliteiten is cruciaal, op alle gebieden. Als netwerk geïntegreerd wil krijgen, moet je alle connecties goed aansluiten.

Stakeholders

- KLM en HSR: zijn bezig met trein-luchtvaart samenwerking met ministerie en anderen partijen, oa KLM en NS. Wordt gekeken naar de verbetering van de connectie tussen luchtvaart en rail. Ook met Thalys in gesprek over hoe dat verbeterd kan worden. Ook bezig met Schiphol daarin om te kijken of er een dedicated balie gemaakt kan worden voor treinreizigers. (Rinze Nieuwhof)
- KLM en hyperloop: Steunen het team van delft hyperloop in de vorm van tickets om naar competitie te gaan. Verder meer een principekwestie om eraan mee te doen. Denk niet dat we er concreet iets mee winnen, maar willen er wel aan bijdragen en zorgen dat er werk van gemaakt wordt en wordt gekeken wat er mee kan. Hardt Hyperloop steunen we vooral met expertise, hebben samen aantal onderzoeken gedaan naar de mogelijkheden om korte vluchten te vervangen. KLM weet veel van het vervoeren van passagiers en goederen, over verschillende afstanden. Als Hardt daar vragen over had kwamen ze vaak bij ons. Ook nog losse studies naar inrichten van security etc.
- NS niet zo belangrijk, want die doet weinig internationaal. Dus vooral Thalys (brussel en parijs) en Eurostar (London). Bij Londen ook problemen met de grens oversteken. Voor Air-rail combinatie vooral de partijen waarmee we praten. Ook met DB contact voor het Duitse stuk.
- Overheidssteun moet je wel ook gewoon hebben om te beginnen. Vooral bij een netwerk, de eerste lijn is heel duur maar de connecties die er daarna bij komen verhogen de waarde van het netwerk. Voor opstart zeker overheidssteun nodig.
- Rondom Schiphol, voor HSR Schiphol zelf en NS en ProRail voor het spoor en de stations. Ook Thalys, want die zijn de enige met een HSR op Schiphol.
- Voor hyperloop vooral met Hardt Hyperloop, ook iets met MRA en gemeente Amsterdam is hierbij nog wel belangrijk.
- Rol van Europa ook zeker van belang. HSR gaat steeds mis op de samenwerking tussen de landen, Europese commissie zou wel dingen moeten. Zeker Europa nodig voor HPT-netwerk want gaat over landsgrenzen heen. Ook goede samenwerking tussen de verschillende landen is van groot belang. De rol van de EC blijft nog maar de vraag.
- Blijft de vraag wie hyperloop gaat operaten, kan hele nieuwe partij maar ook een van de bestaande trein operators of misschien wel KLM. KLM in high-speed alience gestapt, is uiteindelijk niet van de grond gekomen, maar is geen onlogische stap voor KLM om in dit soort initiatieven te stappen en ernaar te kijken.
- Samenwerking met NS om Schiphol beter bereikbaar te maken. KLM ook bezig met het samenstellen van geïntegreerde tickets. In de toekomst uiteindelijk naar MaaS met KLM daar meer als facilitator van vervoer, gegeven de voorwaarden die de reiziger eraan stelt. KLM blijft wel luchtvaartmaatschappij maar ook travel integrator waarin tickets voor verschillende modaliteiten worden verkocht. KLM al eigen Bussen vanaf bijv Eindhoven. Doel KLM uiteindelijk om passagiers van A naar B te brengen op welke manier dan ook.

Attributen

- Na introductie van HSR tussen Londen en Parijs zijn er niet meer vluchten tussen deze steden gekomen, dus wordt zeker ook meer voor HSR gekozen. De toename in de vervoersvraag is vooral opgevangen door HSR op dit traject. Bijvoorbeeld Amsterdam-Brussel vlucht zijn alleen maar mensen op doorreis. Alle directe reizigers gaan met de trein. Als HRS-alternatief biedt dat aantrekkelijker is dan vliegtuig komen de reizigers vanzelf wel.
- Als je heel duurzaam wil reizen kan je met de bus, maar is niet snel en niet comfortabel. De doelgroep die dat doet zijn mensen die duidelijk niet nu voor het vliegtuig kiezen. Mensen die nu voor het vliegtuig kiezen vinden reistijd en comfort het belangrijkste.
- Reistijd blijft zeker ertoe doen, dat wordt niet echt door comfort bepaald. Wordt bepaald door doelgroep. Mensen die voor HSR kiezen zeggen dat veel, het duurt langer maar is ook zeker comfortabeler.
- Als alternatieven beter scoren op deze vier dan vliegen, kiezen mensen daar echt wel voor.
- Frequentie: ook absoluut van belang. Op populaire bestemmingen verhogen we vaak eerder de frequentie dan dat er grotere vliegtuigen worden ingezet. Verhoogde frequentie heeft meerwaarde voor de consument. Blijft altijd een rol spelen.
- Thalys gaat nu net niet frequent genoeg, waardoor de eerste te laat aankomt voor de eerste vluchten van KLM. Integratie tussen HSR, HPT en APT cruciaal.
- Frequentie bouwt ook zekerheid in voor de reiziger. Met hoge frequentie word je flexibeler en zekerder als je een trein mist dat je dan alsnog op je eindbestemming aan komt.
- De behoefte aan meer comfort blijft steeds meer opschuiven, behoefte aan comfort wordt steeds groter. Geldt ook voor wifi, willen passagiers gewoon en gaat ook gebeuren aan boord van alle vliegtuigen over 2 jaar

Appendix G – Interview Noord-Holland

Naam geïnterviewde: Paul Chorus
Organisatie: Provincie Noord-Holland
Datum: 11 februari

Ontwerp

- Hyperloop zou zeker kunnen, maar vergt nog veel tijd. Mensen willen eerst zien dat het echt veilig is en echt werkt. Als je dat op kleine stukken kan laten zien helpt. Ook is het kwestie van geld en dat is er nu gewoon niet. Het mobiliteitsfonds is tot 2030 al uitgegeven, dus dat kun je het bij het Rijk wel vergeten met een hyperloop.
- Het city-to-city op kleinere schaal zie ik niet als iets realistisch. Zou ook kunnen dienen om deel van de druk van het spoor af te halen.
- Stations verder buiten de stad maakt niet zo veel uit, want voor vliegen moet je ook een stukje reizen naar de stad. In Japan zie je dat op afstanden tot 700 km de HSR veel marktaandeel heeft. Is iets langzamer, maar wel stuk meer comfort.
- Voor het intercontinentale liggen er zeker kansen voor HSR en HPT. Als je meteen naar een hyperloop of HRS kan lopen uit het vliegtuig en dat sneller gaat dan nog een vliegtuig, zullen mensen dat zeker doen. Als het een half uur is, is het ook al goed. Mensen willen dan toch wat speling hebben.
- Als het je dichter bij je eindbestemming kan brengen dan vliegen helpt dat ook al mee. Die last-mile is belangrijk. Vanaf die stations moet je ook weer goede verdere verbindingen hebben. Het blijft gaan om de gehele keten.
- Ook voor steden als Eindhoven naar Amsterdam met hyperloop is interessant, dan kan je woon-werk afstand langer worden. Zou ook interessant kunnen zijn als systeem binnen Nederland. Zou er ook een soort intercity plus van kunnen laten maken die op metropool niveau oplossingen kan bieden met snelheid van 300 km/h ofzo. Soort tussenvorm.
- Voor HSR is het boekingssysteem ook een grote bottleneck nu. Het is vaak heel ingewikkeld om allemaal te boeken, met tussendoor weer kaartjes kopen. Nu heel onduidelijk voor internationaal treinverkeer. Het gemak mist nu nog. Als die integratie van alle kaartjes voor de verschillende modaliteiten gaat zoals bij het vliegen nu, scheelt al heel veel. Integratie en centraal regelen is van belang.
- Voor bagage zou je ook kunnen kijken naar het Japanse systeem waar ze je koffer komen ophalen thuis en afleveren waar je naar toe gaat. Dan hoef je niet in zo een volle trein met je bagage. Je kan kijken naar al eerder plekken waar je je bagage kan inchecken en het helemaal door labelen naar je eindbestemming. Los van de modaliteiten die je gebruikt.
- Gemak en prijs zijn het allerbelangrijkste. Nu naar Londen voor 10 euro met vliegen, daar gaat een trein het nooit van winnen. Ook dichter bij de stad aankomen kan echt een voordeel van HSR en HPT zijn tov vliegen.
- Locatie van HSR en HPT Schiphol kan ik me eerder voorstellen dat dat een soort derde terminal wordt die met ene monorail verbonden is met Schiphol. Schiphol is al te vol en is al heel complex. Moet zorgen voor snelle verbinding tussen die HPT, HRS en luchthaven. Zie het als met een treintje gaan naar je departure hal. Als de afstemming en integratie maar goed is.
- Het groeien van Schiphol wordt ook steeds minder geaccepteerd, dus die moeten ook wat anders gaan doen. Die 71 miljoen passagiers is al zo veel, de omgeving gaat heel veel meer niet toestaan op het gebied van geluid.

- Wordt nu eerste ook naar goederenvervoer gekeken, ook om te laten zien dat de technologie ook echt werkt. Gaan we samen met hardt en nog aantal andere partijen op de A4 corridor, de CargoLoop. Nu in december een convenant voor ondertekend. Meer vanuit logistieke kant dus betrokken, maar ook zeker op het gebied van klimaat doelstellingen en regionale mobiliteitsprogramma's is dit interessant. CargoLoop speelt ook belangrijke rol in reduceren van klimaat. Op het gebied van personenvervoer nog geen vervolg, maar is allemaal nog wat verder weg en ook veel scepsis. Komt wel steeds meer aandacht voor het internationale, dat is wel weer interessant. Zou bijv ook verbindingen naar duitsland niet met HSR maar met HPT kunnen doen, HSR ook erg duur.

Stakeholders

- Ik snap dat Schiphol korte afstandsvluchten wil substitueren, maar zij hebben ook een dubbele agenda. Duurzaam vinden ze allemaal prachtig, maar die vluchten die vrijkomen willen zij ook maar al te graag weer benutten voor de intercontinentale vluchten. Zo een hub zou je kunnen worden, maar de uitdaging is hoe je zo een hyperloop in past in het landschap. Bijv op Amsterdam-zuid gaat het al niet lukken. Kijk naar locaties bijv tussen de vangrails, want niemand wil die buis in zijn achtertuin. Het inpassen in het landschap is de grootste uitdaging.
- De overheden moeten erin geloven, ook zeker het Rijk en dat die willen samenwerken met Hardt. Ook voor Hardt zijn de samenwerking met Europa ook erg belangrijk. Als je het daar goed zou kunnen laten aansluiten bij de ambities in de Green Deal, liggen daar zeker kansen. Als EU enthousiast wordt en het ook meer gaat uitdragen helpt zeker. Met zo een nieuwe technologie kan je je als Nederland ook zeker weer goed op de kaart zetten.
- Wij zitten waarschijnlijk meer in de stimulerende rol, financiering denk ik niet. Zit wel belang bij de provincie dat je misschien doelen uit het klimaatakkoord mee kan gaan invullen, daar zit wel een belang.
- NS is niet zo belangrijk, die rol kan iedereen gaan vervullen. Kan ook hele nieuwe partij zijn, maar kan ook KLM zijn voor de operatie. Hoeft niet altijd NS te zijn. ProRail is nu nog niet zo belangrijk, pas met onderhoud en capaciteit van het HSR zijn die van belang. Voor HPT nog onduidelijk wie er over die infrastructuur gaat. NS alleen als je deel van het stations zou willen gebruiken.
- Samen met Hardt heeft Noord-Holland een onderzoek gedaan naar de mogelijkheden van Hyperloop. Zijn samen met de regio en het Rijk bezig met bereikbaarheidsprogramma (Samen Bouwen Aan Bereikbaarheid) en daarin waren we toen bezig met ontwikkelperspectieven voor de metropool Amsterdam. In het scenario compacte metropool zaten ook een aantal internationale verbindingen. Waren benieuwde naar de rol van hyperloop in dat perspectief op die internationale bereikbaarheid.

Attributen

- In Japan zie je dat HSR op afstanden tot 700 km de HSR veel marktaandeel heeft. Is iets langzamer, maar wel stuk meer comfort. Dat gaan mensen steeds belangrijker vinden. Samen met prijs en reistijd is comfort de belangrijkste. Hyperloop comfortabeler dan vliegen ook door bijv geen turbulentie. Ook de mogelijkheid voor internet vinden mensen heel fijn, vooral ook dat mensen dan kunnen werken en andere dingen kunnen doen. Over trein wordt vaak al gezegd reistijd is werktijd, dat is met vliegen toch wat lastiger.
- Uiteindelijk is frequentie belangrijker dan snelheid en dus korte reistijd.

- Gevoel van veiligheid ook belangrij, maar dat komt wel als het meer er is en bijv door cargoloop ook als.
- Gemak en prijs zijn het allerbelangrijkste. Nu naar Londen voor 10 euro met vliegen, daar gaat een trein het nooit van winnen. Ook dichter bij de stad aankomen kan echt een voordeel van HSR en HPT zijn tov vliegen.

Appendix H – Interview ProRail

Naam geïnterviewde: Jeroen Wesdorp & Luuk van Woudenberg
Organisatie: ProRail
Datum: 7 april 2021

Ontwerp

- Het rapport 'verzet de wissel' van Raad voor de leefomgeving zet heel goed uit een wat de grootste barrières zijn voor het gebruik van de internationale trein.
- Belangrijk voor HPT om zijn eigen niche te vinden en niet te focussen op het alleen overnemen van reizigersaantallen. Dat kan de afstand tussen HSR en APT zijn. Dan moet je daar heel erg op in gaan zetten en heel erg voor lobbyen. Gaan welke niche je ook kiest altijd tegenstanders zijn van allerlei partijen (gerelateerd aan andere vervoersmodaliteiten).
- Trein blijft tot 700 km voor mensen die iets langer reizen niet erg vinden een prima alternatief, vooral tussen de grote steden. Vliegtuig gaat ook naar bestemmingen waar de HSR nooit gaat kunnen komen zoals Ibiza. En APT veel vakantie vervoer
- HPT kan misschien ook juist op het stuk dat HSR niet kan faciliteren, zoals naar Madrid. Dan ga je reizigers krijgen van APT.
- De waardering voor reistijd veranderd ook doordat er steeds meer gewerkt wordt tijdens transport. Is geen tijd meer die je verdoet, maar is gewoon werktijd.
- Als luchtvaart duurzaam kan, ben je altijd sneller en goedkoper doordat je geen infrastructuur nodig hebt. Grote kans dat als luchtvaart sneller innoveert dan andere modaliteiten zoals HPT, gaat APT het grote kans gewoon winnen. Snelheid van ontwikkelen is het belangrijkste.
- Het fijnmazige netwerk is een groot voordeel van HPT.
- Stationslocaties HPT: het is het belangrijkste dat je op andere modaliteiten bent aangesloten. Waar mensen heen willen speelt ook een rol in of centrum of airport beter uit komt.

Stakeholders

- ProRail werkt vooral samen met de vervoerders in de verschillende Europese landen, met de beheerders en allerlei overheden door de complexe PPP die in de spoorsector is georganiseerd (vooral op internationaal niveau)
- Niet heel concreet beeld nog van de mogelijke fricties tussen stakeholders
- Eerste partij die je voor HPT nodig hebt is een partij die het financiert. Dat moet het rijk zijn want het gaat over een landelijk besluit, met een landelijk tracé en voor de risico's. Verder raakt het elke overheid op wiens grond het komt te staan en alles en iedereen langs die baan. Als je wil aansluiten op andere modaliteiten zal je daar ook mee moeten samenwerken.
- ProRail vooral betrokken bij het verbinden van HPTstations met de rest van het vervoersnetwerk.
- Ontstaan vooral fricties met partijen waarvan de vervoersvraag beïnvloed wordt door de introductie van HPT. Geldt zowel op het spoor als voor de luchtvaartmaatschappijen, vooral als het op AAS gaat zijn. Elke partij die er al is zal zeggen dat zij dit soort vraagstukken ook kunnen oplossen en er helemaal geen HPT nodig is. Veel gebruikt argument dat de aanleg van HPT alleen maar geld kost en CO_2-uitstoot veroorzaakt. Gemeentes, Provincies, Rijksoverheid etc, iedereen vindt hier wat van.
- Voor HPT spreekt Prorail vooral met SBB en BB, dus Zwitserland en Duitsland. Ook bij European Infrastructure managers wordt dit nu belegd

- Voor HSR is het heel vergelijkbaar met HPT, maar het is wat completer. Op elk niveau hebben we steeds alle spelers aan tafel. We werken dus nauw samen met alles infra beheerders in omringende landen (zowel EU als erbuiten). We werken in opdracht van I&W en vaak ook van de concessie verlenende provincies en hebben te maken met elke overheid waar het spoor door heen loopt. Ook natuurlijk met alle partijen die de treinen rijden en in het aannemers en onderhoudsdomein.
- NS rijdt niet zo veel internationale treinen, maar verkoopt vooral namens verschillende partijen kaartjes en vraagt de capaciteit aan. NS vooral een nationale vervoerder, hoe meer er internationaal gereden gaat worden door hen, hoe meer ze ook hun eigen nationale belang in de weg gaan zitten. Het is nu al een open markt, maar dat kan nog zeker verder.
- Rol EC en Europa: zeker voor HPT hele belangrijke rol. Op middellange afstanden zit daar vooral de winst, is heel veel afstemming voor nodig en is grensoverschrijdend, moet je Europees trekken. Hetzelfde geldt voor HSR, zijn nu ook bezig met het internationaal regelen van het trein beveiligingssysteem. Europa cruciaal voor het verder integreren. Europa is wel ook maar gewoon een samenwerking tussen landen die zelf bepalen hoe ver dat gaat. Het contact tussen bijv twee landen blijft ook heel belangrijk. EC trekt het proces om Europees te blijven denken en zorgt dat dat gewaarborgd en gefaciliteerd kan worden.
- Ook bij financiële steun en Europese integratie is Europa van groot belang, heeft een faciliterende rol.
- Het aantal partijen dat echt belang heeft bij het ontwikkelen van de hyperloop is heel beperkt. Vooral ook heel veel partijen die HPT wel willen volgen maar niet actief actie op ondernemen. Veel partijen houden toch hun eigen belang. Er is nog geen concrete markt voor HPT, dat heb je wel nodig.
- ProRail vooral betrokken bij HPT in het koppelen van modaliteiten, zoals ze dat nu ook doen met de bus, trein en tram. In Nederland zijn wij de grootste partij die dat kan. Daar valt nu veel winst te behalen. Het zou kunnen dat wij misschien wel de HPT infrastructuur gaan beheren, maar dat is nog heel erg onzeker.
- Rijksoverheid cruciaal, ook voor subsidies. Zij moeten het vertrouwen hebben dat het een probleem gaat oplossen. Er moet een ambitie zijn vanuit Rijksoverheid. Moet een incentive creëren voor partijen om erin te stappen, daar zijn subsidies en dus de overheid cruciaal. ProRail is dan een van de eerste partijen waar Rijksoverheid terecht gaat komen.
- Het stakeholder veld is ook complex door alle verschillende belangen. KLM bijvoorbeeld wil wel, maar willen ook hun eigen business beschermen.

Appendix I – Input Hardt Hyperloop

Various personal discussions took place with Hardt Hyperloop on a wide variety of topics. This thesis was written in collaboration with Hardt Hyperloop. No formal interview took place with Hard Hyperloop.

Appendix J – Interview SEO

Naam geïnterviewde: Christiaan Behrens (Transport econoom)
Organisatie: SEO
Datum: 9 feb 2021

Ontwerp

- Er is veel discussie geweest over een Europees netwerk voor HSR. Deze discussie wordt nu met hyperloop weer opnieuw gevoerd. Moet er bij hyperloop wel voor zorgen dat er concurrentie is op het netwerk zoals bij luchtvaart, anders komt er overheidsmonopoly. In luchtvaat geldt one single sky agreement, iedereen mag overal naar toe vliegen. Met de treinen is dat veel complexer. NS mag niet zomaar bijvoorbeeld in Italië rijden, veel meer integratie nodig en veel meer langdurige beleidvorming.
- Er zullen altijd directe vluchten blijven tussen de grote Europese steden en de rest van de wereld. Het feeder verkeer is daardoor lastig, dus de vraag is of het echt om doorvervoer zal gaan. Bij HSR tot nu toe meer op en neer verkeer tussen bijvoorbeeld Londen en Parijs. De waarde van een directe connectie blijft heel hoog. De kracht van trein en evt hyperloop is dat ze in het stadscentrum aan komen, speelt hele belangrijke rol in modaliteitskeuze. Schiphol dan het voordeel dat ze dicht bij het centrum liggen.
- Hele goede integratie maakt zeker verschil. Hoe makkelijker de connectie, hoe beter. Bijvoorbeeld bagage door labelen en doorsluizen en 1 ticket is een belangrijke. AirFrance-KLM doet dat al heel goed met integreren van trein en luchtvaart. Als dat goedkoper en netter kan zitten daar zeker kansen.
- Wat altijd beetje vergeten wordt is dat als je trein beter maakt, dan raak je korte-afstandsvluchten kwijt. Maar dit levert ruimte op op luchthavens, waardoor luchtvaartmaatschappijen meer op bijv China gaan vliegen, waardoor je alleen maar meer passagiers op de luchthavens krijgt. Daar zit de winst voor luchthavens, lange afstand levert meer geld op dan korte. Ook het naïeve aan het huidige beleid waarin wordt ingezet op HSR en HPT voor het schoner en beter maken van het transport. Dat gebeurt alleen als de capaciteit van Schiphol op papier worden verlaagd. De gemiddelde uitstoot zal wel om laag gaan, maar de totale uitstoot helemaal niet. Maakt het mogelijk om meer verkeer op de luchthaven te genereren. Niet heilig geloven in het idee dat HPT en HSR leiden tot minder vliegen, de afstanden van de vluchten worden alleen langer. Is niet slecht vanuit maatschappelijk perspectief, maar hangt van het doel af dat je voor ogen hebt: meer geld of uitstoot verminderen.
- HPT gaat tegen dezelfde problemen aanlopen als HSR: Integratie, over landsgrenzen heen. Als dat voor HSR niet gelukt is, waarom dan wel voor HPT. Daarnaast denk ik zeker dat het een alternatief kan zijn naast HSR.
- Het enige unieke van een hyperloop zou kunnen zijn dat je ook kleinere plaatsen kan aansluiten op het systeem zonder dat de snelheid over de hele route naar beneden gaat. Dit kan door gewoon enkele pods bijv van Gouda naar Parijs te laten gaan die invoegen in de connectie van Amsterdam naar Parijs. Kan veel efficiënter kleinere steden aansluiten dan met HSR. Met HSR gaat als je meer tussenstops hebt, de snelheid heel snel omlaag. Afweging tussen meer stops en dus meer mensen en lagere snelheden. HPT is dus een fijnmaziger netwerk zonder daarbij snelheid te verliezen. Krijgt ook een veel groter bereik doordat je ook iedereen die op bijv de lijn van Amsterdam naar Frankfurt kunnen er ook gebruik van maken, zonder dat snelheid van

de connectie Amsterdam-Frankfurt omlaaggaat. Dit conceptueel gezien het enige interessante verschil tussen HSR en HPT.

- Bij Schiphol is het al behoorlijk vol, dus kan me voorstellen dat die stations ergens op een weiland bij hoofddorp komen te staan met bijv een people-mover tussen Schiphol en die stations. Ideaal gezien is het Schiphol van de toekomst helemaal geïntegreerd, waar HSR en HPT ook gaan. Dat gaan wij alleen zeker niet meer meemaken mocht dat gebeuren. Het doortrekken van een metrolijn kost al minimaal 10 jaar nu, en is nog niet eens financiering, dan nog Tracébesluit. Kost minimaal 20 jaar voor dat er ligt. En dat alleen bij een simpele metrolijn. Het idee dat je zo een HPT-netwerk neerlegt is kansloos. In China en Midden-oosten meer kansen: autoritairder en minder democratisch (overheid meer macht), veel geld over en de transportproblemen zijn daar veel groter wat tot hogere urgentie leidt.
- Locatie waar je bij een stad aan komt is van groot belang. Kracht van HSR en evt HPT dat je in centrum aan komt en dus veel minder voor en na transport zal hebben.
- Door labelen van bagage en integratie van veiligheidscontroles zodat je niet nog een keer veiligheidscontrole. Comfort en integratie zeker van belang (transfer substitutie)
- Ook locatie van station en dus geen voor en na transport hoeven doen is van belang. Blijft bij vliegen meer. Als dit wegvalt mag je voor de meeste mensen wat langzamer zijn.
- Hoe ver van tevoren boeken maakt voor lange reizen niet uit, bijv. uit china. Mensen zijn dan toch hun hele reis al aan het plannen. Inter-Europees wel toegevoegde waarde om dag van tevoren te boeken, maar speelt stuk minder een rol. Naarmate de afstand langer wordt, gaan mensen van tevoren al meer plannen, minder spontaan, dus dat wordt tijd die je van tevoren moet boeken minder belangrijk. Dit geldt ook voor aankomsttijd, je gaat er toch al omheen plannen.

Stakeholders

- Als je een hub voor Europa wil creëren krijg je daar ook weer concurrentie op tussen de landen. Iedereen wil die Europese hub worden.
- Vooral de sterke urgentie om op Europees niveau samen te werken in het creëren van een Europees netwerk, integratie is nodig. Ook moeten er hele grote investeringen gemaakt worden voor de infrastructuur. Landschap speelt ook een rol, bijv berggebieden. Dus ook echt fysieke problemen.
- Vanuit Nederland vooral heel belangrijk om lobby te voeren in Brussel, macht bij Europa heel belangrijk. Daar zit de macht en het geld om de rest van Europa erop aan te sluiten. Ook de Europese hoofdsteden zelf, misschien nog belangrijker dan Brussel. De steden zelf bepalen waar de treinen naar toe gaan. Europees netwerk moet op Europees beslissing zijn over hoe netwerk eruit gaat zien. Als land alleen kom je nergens. Puur Europa.
- In Nederland zie je dat Schiphol dit wil, I&W vindt het daardoor ook wel interessant. Het is nog helemaal niet zeker wie HSR en HPT gaat rijden, dus NS deels interesse. Om dit voor elkaar te krijgen heb je zo veel geld nodig om infrastructuur neer te kunnen leggen. Kan geen privaat bedrijf doen, moet heel veel overheidsgeld krijgen.
- In landen als China en Saoedi-Arabië nog meer kansen omdat daar overheid meer macht heeft en meer ruimte.

- Integratie en lokaal afstemmen levert ook zeker problemen op.
- Ook de vraag wie welk traject mag gaan rijden kan tot frictie tussen stakeholders zorgen. Iedereen wil de drukst bezette trajecten rijden, maar die worden vaak aan 1 operator gegund. Dit is wel ook wat het ook interessanter maakt om het hele netwerk te gaan bedienen.
- Concurrentie op het spoor heel ingewikkeld, hoewel bij luchtvaart ook kan. Komt vooral door de hoge vaste kosten die verbonden zijn aan het railnetwerk (moet met publiek geld worden neergelegd) maar toegang moet blijven concurreren. Daar zit grote bottleneck. Luchtvaart op dat gebied eigenlijk 10 a 15 jaar verder.
- Op het gebied van besluitvorming heb je nu wel de groene wind mee, wat in voordeel van HSR en HPT zou kunnen zijn. Aankomend decennium gaan daar mogelijk besluiten over HSR komen. Iedereen wil verduurzamen en ten tweede is er steeds meer een conservatieve wind die zegt dat de overheid een grotere rol moet gaan spelen in plaats van alles door de markt. Die twee kunnen wat meer groene autoriteit bij Europa neerleggen, geeft potentie voor HRS-netwerk, maar blijft heel incrementeel proces waarin steeds kleine stukken worden aangelegd. Gaat om grote investeringen voor kleine verbeteringen. Welke stukken dan sneller verbonden mogen worden is ook een lobby. In 2050 vooral op city-pair niveau een slag gemaakt, maar geen integraal Europees transportsysteem. Allemaal via bilaterale afspraken. Gaat niet zo worden als de luchtvaart.

Attributen

- Prijs echt de belangrijkste, moet concurrerend zijn.
- Bij HPT speelt ook zeker mee of mensen er in durven te stappen, het gevoel van veiligheid, altijd met iets nieuws. MagLev ongelukken bij Hamburg laten dit heel goed zien. Ook met de Concorde, heel nuttig voor HPT.
- Belangrijk is ook comfort, mensen vinden nu trein comfortabeler dan het vliegtuig. Kunnen daarin bewegen, zitten, werken. De waardering voor reistijd wordt lager, maakt mensen minder uit als ze ook andere dingen kunnen doen. Reistijd waardering ongeveer de helft van je uurloon (rule of thumb). Gaat niet tot het oneindige door wat je reist met een bepaald doel, vaak een afspraak bijv.
- Aanbod van het aantal vetrektijden dat er is. Keuze in tijden van de dag. Komt steeds dichter bij gewenste tijd te liggen met hogere frequentie. Gaat erom wanneer mensen aan willen komen bij hun eindbestemming. Iedereen wil andere aankomsttijd hebben, dus frequentie doet er zeker toe.

Appendix K – Interview TU Delft

Naam geïnterviewde: Bert van Wee
Organisatie: TU Delft
Datum: 23 feb 2021

Hyperloop

- Denk dat het er niet komt. Puur op basis van het verleden als je kijkt naar transport innovaties, zijn er stukken meer die het niet gered hebben dan wel. Historisch onderzoek suggereert eerder niet dan wel.
- Kans dat hij er wel komt lijkt me kleiner dan dat hij er niet komt
- Hoewel dat dan geldt voor alle kandidaat innovaties. Als je kijkt naar de ontwikkeling van de transportmarkt over de afgelopen 200 jaar is er veel veranderd. Hyperloop is wel een potentiele kandidaat hiervoor. Met name, net als HSR, als de luchtvaart aan banden wordt gelegd.
- Duurzamer worden van de luchtvaart is een onzekerheid. Elektrisch vliegen is heel onzeker nog dat dat gaat gebeuren. Blijven dan nog duurzame kerosine (complex), waterstof (vliegtuig herontwerp nodig) en e-fuels (verbrandingsproces wordt omgedraaid ten opzichte van nu, huidige vliegtuigen kunnen in gebruik blijven, maar wel veel meer energie nodig en duur). Als er doorbraken komen op dit gebied past het de concurrentie van HSR en HPT aan, maar luchtvaart innovatie gaat nog lang duren en gaat ook zorgen voor hogere prijzen bij de luchtvaart.
- Nadeel hyperloop is de infrastructuur, maar komt ook dichter bij bestemmingen aan.
- Success in andere landen heel belangrijk om HPT ook in Europa van de grond te krijgen

Ontwerp

- Het aantal kilometers dat mensen gaan reizen neemt toe als bereikbaarheid toeneemt. Effect van ICT op de som van alle verplaatsingstijd blijkt klein, mensen blijven wel die 01:15 uur reizen per dag. Onder de streep geen effect op reistijd
- Ticket integratie kan technisch gezien best, maar wat betreft de houding van stakeholders die hiervoor nodig is, is Bert van Wee niet optimistisch.
- Organisaties als Rover is al jaren aan het klagen over slechte ticket service van het OV, maar veranderd heel weinig. Hebben bijvoorbeeld ook nog steeds geen single check-in check-out.
- Ook op internationaal gebied veel slechter geregeld als je bijvoorbeeld aansluitingen mist. Bij luchtvaart veel beter geregeld. Uit veel onderzoeken blijkt dat ticketing informatie heel belangrijk is voor mensen en zelfs een barrière is voor het reizen met de trein op internationaal niveau. Over de voortvarendheid van het oplossen van dit probleem ben ik niet erg optimistisch.
- Vervoerders willen hun tickets niet door anderen laten verkopen. Rail-sector niet klantgericht en vooral op netwerk in stations gericht. Overheden zouden hier meer macht op uit kunnen oefen. Geven veel subsidies vanuit de overheid aan de vervoerders, daar zou je ook best wat voor terug kunnen vragen. Waarom niet gebeurt blijft onduidelijk. Blijft grote macht bij de rail sector liggen.
- Ticket integratie zou het maatschappelijke rendement van rail stukken kunnen vergroten. Rail veel conservatiever dan luchtvaart. Zijn harde regels nodig om dit voor elkaar te krijgen.
- Luchtvaartmaatschappijen zijn ook veel bezig met ticket integratie, maar zitten ook haken en ogen aan op juridisch gebied.

- Bij hyperloop is de eerste vraag wie hyperloop gaat uitvoeren. Als dat de huidige treinvervoerders zijn, ben ik niet erg optimistisch dat het beter gaat zijn. In veel innovatie literatuur blijkt wel dat de new-comers wel stukken beter zijn met dit soort grote veranderingen dan al bestaande bedrijven. Liggen wel mogelijkheden. Bij luchtvaart bijvoorbeeld allianties.
- Verwacht dat hyperloop meer op de luchtvaart gaat lijken op het gebied van tickets etc dan op de rail.
- De veranderingen in de luchtvaart op het gebied van klimaat (BTW op tickets en kerosine, subsidie bevoordeeld luchtvaart) zijn van groot belang in de vraag of rail wel of niet kans maakt op luchtvaart te substitueren. Als strenger wordt opgetreden in de luchtvaartsector worden kansen voor rail groter. Ook de mate waarin de luchtvaart zelf gaat investeren in innovatie speelt een rol. Ook de vraag van de maatschappij speelt een rol (vliegschaamte en druk vanuit bedrijven of minder te vliegen). Bepalende factoren voor of HPT en HRS goede alternatieven kunnen zijn voor APT. Op sommige trajecten zie je dit al, wel alleen directe verbindingen van niet zo complexe reizen.
- Hyperloop stations komen dichterbij de stad te liggen waarschijnlijk dan luchthavens, hoeft niet perse in het stadscentrum te zijn. Locatie van stations is zeker belangrijk. Voor- en na transport vinden mensen vervelend. Op locatie van stations is HPT dus meer een trein. Amsterdam centraal voor HPT geen optie. Zuid of Schiphol is dan voor de hand liggender.
- Frequentie van HPT wordt waarschijnlijk hoger, maakt het integreren van tickets makkelijker dan voor een minder frequent rijdende HSR.
- Bij trein vaak niet langer dan 3 maanden van tevoren boeken, voor veel mensen te kort van tevoren dus boeken dan toch maar een goedkoop vliegticket. Werkt in het nadeel van de trein.
- Veiligheidscontroles: vaak reactief. Eerst aanslagen dan roep om meer veiligheid. Hangt er dus ook vanaf hoe dat bij hyperloop en HSR gaat. Vind het lastig hier uitstpraak over te doen. Vliegtuig gaat wel de lucht in en zal alleen maar strenger worden voor vliegen. Ook ontwikkelingen in controle technologie van belang
- Gezondheidscontroles lijkt nu belangrijk maar als pandemie weer voorbij is ook snel weer weg. Als er weer een virus komt, wordt het wel waarschijnlijk sneller, van tijdelijke aard ingevoerd of zelfs het reizen als geheel wordt gestopt.

Stakeholders

- Ticket integratie kan technisch gezien best, maar wat betreft de houding van stakeholders die hiervoor nodig is, is Bert van Wee niet optimistisch. Organisaties als Rover is al jaren aan het klagen over slechte ticket service van het OV, maar veranderd heel weinig. Hebben bijvoorbeeld ook nog steeds geen single check-in check-out. Ook op internationaal gebied veel slechter geregeld als je bijvoorbeeld aansluitingen mist. Bij luchtvaart veel beter geregeld. Uit veel onderzoeken blijkt dat ticketing informatie heel belangrijk is voor mensen en zelfs een barrière is voor het reizen met de trein op internationaal niveau. Over de voortvarendheid van het oplossen van dit probleem ben ik niet erg optimistisch.
- Stakeholder samenwerking superbelangrijk. Blijkt ook als je naar de geschiedenis gaat. Ook als HPT helemaal geprivatiseerd is moeten overheden toestemming geven. Is Europa, landen, provincies, gemeenten. Iedereen langs een lijn willen een station, maar dat kan niet.
- Zijn operators nodig
- Integratie met andere systemen

- Nieuwe systemen ontstaan niet in een keer helemaal, gebeurt in delen. Eerst een paar verbindingen. Misschien gewoon wel met 1. Vanuit door doortrekken en uitbreiden. Trasport netwerken ontwikkelen zicht evolutionair
- Rol Europa heeft sterke focus op trans-European netwerken voor zowel economische als integratie doelen, misschien wel te veel. Ook heeft Europa belangrijke rol in het luchtvaartbeleid, op Europees niveau moeten bijvoorbeeld belastingen worden ingevoerd om de klimaat doelen te behalen. Doordat hyperloop grensoverschrijdend is wordt Europa ook daarvoor van belang
- Europa voor het leggen van netwerk belangrijk, maar wel ook private partijen nodig die dat ook daadwerkelijk willen aanleggen en willen investeren.
- EU ook voor voertuig regelgeving een belangrijke rol. Eisen aan hyperloop moeten op Europees niveau worden ingesteld. Bij rail dus nog steeds niet zo

Attributen
- Reistijd (deur-tot-deur)
- Reiskosten
- Comfort in trein beter dan in vliegtuig verwacht
- Vliegangst is er wel, treinangst bijvoorbeeld nog niet
- Vliegschaamte en klimaat
- Onderscheid tussen motieven: zakelijk en overige. Vaak wordt zakelijk vliegen ook gecombineerd met toeristische motieven. Evt ook meenemen in DCM. Niet zo makkelijk te onderscheiden als in de transport literatuur gebeurt. Heeft u uw zakelijke reizen gecombineerd met toeristische activiteiten? Is de keuze om een reis al dan niet te maken hierdoor beïnvloed.

Appendix L – Interview Berenschot

Naam geïnterviewde: Kaj Mook

Organisatie: Berenschot, vroeger NS International

Datum: 4 maart 2021

Ontwerp

- Ticket integratie: vaak in air-rail debat wordt genoemd dat het gemak van het boeken van een treinticket achter blijft bij het boeken van een vliegticket. Soms wordt ook wel ook een beetje als een dogma gebruikt, voor groot deel van de bestemmingen is het bij rail ook op orde. Maar veel voor te zeggen om rail veel meer zichtbaar te maken voor klanten, nu vooral luchtvaart. Ideaal zou je 1 ticket voor je gehele OD reis willen. Technische gezien verwacht ik ook zeker dat dat tot stand gaat komen. Partijen als Transer in NL, maar ook andere MaaS achtige partijen. De uitdaging zit vooral in het juridische en businessmodel. Als je ergens je ticket boekt is die partij ook verantwoordelijk dat jij op je eindbestemming komt. Voor geen van de partijen die een segment van die reis doen is het interessant om de gehele verantwoordelijkheid te nemen. Over 10 jaar verwacht ik dat technische barrières wel zijn opgelost, maar of de barrières rondom reisrechten om het dan ook commercieel aantrekkelijk te maken ook zijn opgelost, daar heb ik nog wel mijn twijfels over.
    - Overkoepelende ticket integrator zou logische zijn voor verantwoordelijk, maar uiteindelijk kan die partij dat niet afdwingen. Die koppelen reissegmenten aan elkaar, aar niet verantwoordelijk. De vraag is of er een voor de klant aantrekkelijk product aangeboden gaat kunnen worden.
    - Voor HPT als je het beperkt tot bijv voor en na transport met trein kan het wel lukken, zelfde geldt voor HSR. Als je lokale en regionale vervoer eraan wil koppelen wordt dat lastiger. Maakt dat niet heel veel uit of het een nieuwe hyperloop is of een al bestaande HSR. De kleine schaal is het lastigste om te koppelen.
    - EC wil ook multimodale tickets bevorderen. Europa zou initiatief kunnen nemen om multimodale ticketing te realiseren. Misschien beginnen met aantal hoofdverbindingen en dan verder langzaam uitbreiden door de aantrekkelijkheid van systeem. Dan zullen steeds meer partijen willen, maar in eerste instantie niet op dat allerlaatste stukje van de reis focussen.
- Het aantrekkelijker maken van HSR zit ook deels in marketing. Bijv bij Berlijn, niets veranderd maar 20% meer reizigers zonder iets aan de verbinding te veranderen, alleen al door meer onder de aandacht brengen.
- HSR moet meer in de keuze set van mensen komen.
- Hyperloop kracht vooral ook op de verdere afstand dan HSR, dus boven de 600-700 km. In dat hogere segment alleen nog nachttrein eigenlijk, maar heeft lage capaciteit. Op afstanden tot 2000 km heeft hyperloop de potentie om vluchten wil vervangen.
- Hyperloop development program ook al goed als er geen HPT komt. Er is potentieel marktruimte voor HPT op die afstanden en misschien ook op kortere afstanden. Moeten ook focussen op trajecten waar nog minder goede HSR ligt, anders wordt het een maatschappelijk-sociaal lastige kwestie. Op trajecten die nog minder zijn voorzien zijn er wel kansen.
- Wat HSR op HPT voor heeft is dat HSR makkelijk te koppelen is aan het al bestaande spoor, je hoeft het dus niet van A tot B aan te leggen. Inpassingsproblematiek voor HPT stuk lastiger, ook vanuit klant perspectief. Als je niet oppast met die stationslocaties creëren je eindelijk alleen

maar een extra schakel als het weer een eigen locatie zou krijgen. Dat is een uitdaging. Ten tweede heeft HPT ook dezelfde nadelen als andere infrastructuur gebonden modaliteiten dat het gefixeerd is. Dure infra op een specifieke route is nodig, maar niet flexibel. Kost heel veel geld en tijd om dat voor elkaar te krijgen. Dat probleem heeft HSR ook, maar lost HPT ook niet op. Mist ook flexibiliteit die luchtvaart wel heeft.

- In ontwerp heel belangrijk om te kiezen voor HSR waar je je op richt, ga je APT substitueren en dus focus op connectie met de luchthaven of focussen je op kracht van het brengen van mensen naar het stadshart.
- Op het gebied van aantal locaties biedt HPT nog meer opties dan bij HSR. Kan pods laten in en uitvoegen vanaf verschillende locaties. Maakt het iets flexibelere dan traditioneel spoor. Kan zowel van binnenstad naar binnenstad als van binnenstad naar luchthaven en luchthaven naar luchthaven aanbieden. Zijn twee marken die je anders moet gaan bedienen.
- HPT stations op CS gaat nooit lukken, Zuid nog meer kanshebber, maar is ook altijd een punt van discussie of het nou goed idee is om zuid zo een internationaal trein station te maken. Denk wel dat je met HPT moet zorgen dat je op zuid uit komt en het zo neerzetten dat je in het hart van Amsterdam aan komt. Zijn vanaf daar ook genoeg connecties. Als je op Schiphol stopt, voelt het alsof je nog een overstap moet maken voor je in het centrum bent, dat zou ik dan weer niet aanraden.
- Veiligheidscontroles: bij Eurostar veiligheidscontroles vooral voor de kanaal tunnel gedaan. Kan me voorstellen dat het ook om die reden om infra te beschermen er wel komt. Dan speelt ook de vraag hoe efficiënt je die securityprocessen kan inrichten. Dat is toch wel een voordeel van trein tov APT wat je wil vasthouden. Technologie speelt daar ook belagnrijke rol in en wie weet zorgt dat er ook wel voor dat het heel snel kan gaan.
    - Komt wel een vorm van veiligheidscontroles bij HSR en HPT, maar niet perse zoals bij APT. Moet sneller en krijgt niet dat hangen op een luchthaven.
- Gezondheidscontroles vind ik lastig om wat over te zeggen, is zeker niet uitgesloten. Maar HPT-capsule heeft dan wel weer een voordeel dat het een vrij geconditioneerd systeem is, net als bij vliegen. HSR is veel meer open. Kan iedereen makkelijker screenen voor ze die pod in stappen.
- Bagage integratie kan je als luchthaven ook meer in doen dan als luchtvaartmaatschappij en treinexploitant. Als vervoerder ben je makkelijker in te wisselen, als luchthaven ben je vast.
- Voor spoor niet per definitie interessant om voor lage prijzen luchtvaart passagiers over te nemen en andersom daar ook. Daar kan regulering zeker wel een rol spelen om dat wel plaats te laten vinden.
- Schiphol heeft ook doelstellingen over hoeveel mensen met de auto en de trein naar de luchthaven moeten komen. Dat zou je ook kunnen doen voor de langere afstanden met luchtvaart en trein
- Bagage integratie: Het feit dat in het vliegtuig je koffer niet bij je hebt is niet per se zo omdat het de beste oplossing voor de klant is, maar gewoon door hoe een vliegtuig is ontworpen. Dat wordt vaak neergezet als de norm, maar hoeft niet zo te zijn. Maar het trein model heeft ook nadelen als mensen veel bagage hebben. Veel reizigers hebben alleen maar handbagage, die reizigers moet je het zo makkelijk mogelijk maken over de gehele keten. Kan alsnog delen incheckte zijn, maar dan moet de transitie van het ene naar het andere systeem sneller. De overstaptijd tussen modaliteiten moet niet langer duren dan tussen dezelfde modaliteiten. Betere afstemming is daarvoor nodig.

Stakeholders

- Ticket integratie: Partijen als Transer in NL, maar ook andere MaaS achtige partijen. De uitdaging zit vooral in het juridische en businessmodel. Europa ook zeker een rol.
- Belangrijkste stakeholders om tot HPT verbindingen te komen zijn zeker overheden. Regionale overheden misschien nog wel meer dat nationale. Regionale moeten het agenderen zodat het in Den Haag op tafel komt. Dat gaat Den Haag zelf nooit bedenken. Regio's en landsdelen moeten vooral hard gaan roepen dat bijv hyperloop nodig is. Heb aan allebei de kanten van de verbindingen een goede lobby nodig. Dan komt het op nationaal niveau op de agenda.
- Voor het maken van de optimale Air-Rail- HPT connectie moet het vooral van de luchthaven exploitanten komen. Zowel luchtvaart als spoorwegmaatschappijen zeggen dit is hoe wij het doen en laat de ander zich er maar op aan passen, ik zie daar weinig bereidheid tot het ontwikkelen van een nieuwe propositie. Ook omdat de economische prikkels niet de goede kant op staan en ze ook potentiele concurrenten zijn voor het vervoeren van passagiers. Dat geldt niet voor de luchthaven.
- Voor AAS maakt het niet uit met welke modaliteiten ze als knooppunt belangrijk blijven, zolang ze maar belangrijk blijven. KLM en NS zien elkaar nu als concurrentie, maar die samenwerking zijn wel heel belangrijk voor integratie.
- Voor bagage integratie ook vooral naar Schiphol
- Ook interessant dat altijd alleen met KLM en NS wordt gepraat hoewel er heel veel andere luchtvaart exploitanten zijn en potentieel ook andere trein exploitanten.
- Een luchthaven maakt met iets meer langere termijnvisie dit soort investeringen doen. Moet nooit in splended isolation zo een systeem aanleggen.
- Luchthaven belangrijke rol als mediator om tot gezamenlijke actie komen. Meer ook dan een overheid. Overheden gaan reguleren en dat kan ook juist weer de verkeerde kant op gaan. Goed reguleren is best moeilijk en maatwerk. Is een risico van overheidsbetrokkenheid. Kan alleen maar tot kosten leiden en net niet tot de oplossing die het beste voor reizigers zijn.
- Bagage integratie: begint weer met luchthaven infrastructuur die alles op elkaar aansluit. Wel ook weer in overleg met luchtvaartmaatschappijen. Zelf geloof ik niet zo veel in bagagecompartimenten in treinen, dus zou vooral voor transfer zijn.

Appendix M – Stakeholder analysis and categorisation

In this appendix an overview is given of the main stakeholders. For each stakeholder their role, interests and objectives are formulated. Six catagories of stakeholders are defined: transport facilitators, transport operators, (inter)national government bodies, regional& local government bodies, traveller representatives and other stakeholders. NS and KLM are included as operators of respectively HSR and APT. However, this is not yet a certainty, since other parties could also come into play to operate HSR of APT. Furthermore, Hardt Hyperloop is for now divided into an operator and a facilitator. It is not yet clear who will operate and/or facilitate HPT.

Table 27: Stakeholder overview

Stakeholders	*Role*	*Interests*	*Objectives*
		Facilitators of long-distance transport	
Royal Schiphol Group (problem owner)	Owns infrastructure for APT	Quality of life, quality of network and quality of service are at the core of our vision for the future. We want to be the world's most sustainable and high-quality airports. To achieve this, connecting the Netherlands with the rest of the world while minimising our impact on the living environment and climate is essential.[53]	Become the multi-modal hub in Europe and reduce its environmental footprint. Focus in this is mainly on short-haul flight substitution within Europe and on exploring potential impact of transport over land and of innovative modes such as hyperloop[54]. Schiphol is a crucial stakeholder, since it facilitates all three modalities when it becomes a large multi-modal hub.
ProRail	Owns infrastructure for HSR	Responsible for the rail infrastructure in the Netherlands. Aim of ProRail is the increase the number of trains running, in a safe way, with less hindrance, now and in the future. This is done with attention for both environmental impact and for societal impact. [55]	Increase the number of (international) trains running. Collaborates with NS to realise a better HSR network.[56] Is needed for the construction, adjustment and maintenance of the rail infrastructure.
Hardt Hyperloop (client) (infrastructure)	Owns infrastructure for HPT	Creating an on-demand, affordable transport system in which people can travel huge distances in a short time, all completely emission-free, safe and accessible for everyone. People will be able to live and work wherever they choose, and consequently expand their boundaries. Connecting the world.[57]	Introduce hyperloop at Amsterdam Airport Schiphol and create an on-demand, affordable transport system in which people can travel huge distances in a short time.
		Transport operators	

[53] https://www.schiphol.nl/en/schiphol-group/page/strategy/
[54] Schiphol Group. (2018b). *Slim én duurzaam - Actieplan luchtvaart nederland: 35% minder CO2 in 2030*.
[55] https://www.prorail.nl/over-ons/wat-doet-prorail
[56] https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/rapporten/2018/09/27/bijlage-2-lange-termijnvisie-hsl/bijlage-2-lange-termijnvisie-hsl.pdf
[57] https://hardt.global/about-us/

KLM	APT operator	Strives for profitable growth in order to achieve its own goals and to contribute to the general economic and social development. Want to create sustainable development at Amsterdam Airport Schiphol and want to gain access to every market that contributes to enlarging their network quality. [58]	Focus on mainport flights and increase this international network. The substitution of short-haul flights contributes to that. Important stakeholder in the exploitations phase of HPT. Wants to maximize use of APT and maximize profit. Is also seriously considering options to become more of a travel facilitator, including different transport modes.
NS	HSR operator	Travel wherever you want, as comfortably as possible, while taking the environment and future generations into account. [59]	Increase the HSR network to maximize the number of users and in order to substitute short-haul flights. Collaborates with ProRail to realise a better HSR network.[60] Main player to facilitate HSR in the Netherlands. Needs to be willing to collaborate on a European level and is largely involved with that respect. Wants to maximize HSR use in order to maximize profit.
Hardt Hyperloop (operation)	HPT operator	Creating an on-demand, affordable transport system in which people can travel huge distances in a short time, all completely emission-free, safe and accessible for everyone. People will be able to live and work wherever they choose, and consequently expand their boundaries. Connecting the world.[61]	Increase the number of HPT users in order to maximize profit.
GVB	Operator and facilitator of regional/local public transport	Work on an attractive, accessible and sustainable public transport network in Amsterdam. Also strive to minimize impact of their services on local residents. In addition, contribute to the social and economic growth of the city and region.	Come into play when new HPT stations would be constructed. GVB plays an important role in making those stations accessible. [62]
(Inter)National governmental bodies			
European Commission	Regulates and invested in HPT	Become the first climate neutral continent, make Europe fit for a new generation of technologies, create an economy that works for people, a stronger Europe in the world, promote the European way of life and protect our democracy.[63]	Part of European Hyperloop Development Initiative: want to support the road to market of disruptive European initiatives that increase efficiency, availability and sustainability of the current transport network. Achieve in interoperable hyperloop system and achieve scalability for long-distance routes in Europe and globally so society can benefit from the system.[64]

[58] https://www.klm.com/travel/nl_nl/corporate/company_profile.htm
[59] https://www.ns.nl/over-ns/wie-zijn-wij/visie.html
[60] https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/rapporten/2018/09/27/bijlage-2-lange-termijnvisie-hsl/bijlage-2-lange-termijnvisie-hsl.pdf
[61] https://hardt.global/about-us/
[62] https://over.gvb.nl/organisatie/profiel/
[63] https://ec.europa.eu/info/strategy/priorities-2019-2024_en
[64] https://ec.europa.eu/eipp/desktop/nl/projects/project-11397.html

Dutch Central Government	Regulate and invested in HPT	Work on an equitable, entrepreneurial and sustainable society.[65]	Grant subsidies for hyperloop development[66]. General interest in accessibility and development of mobility in the Netherlands. Mainly needed in the realisation phase for the construction of an elaborate HSR and HPT network.
Ministry of Infrastructure & Water Management (I&W)	Provide connectivity and accessibility of the Netherlands. Mainly important in the realisation phase.	The Ministry of Infrastructure and Water Management is committed to improving quality of life, access and mobility in a clean, safe and sustainable environment. The Ministry strives to create an efficient network of roads, railways, waterways and airways, effective water management to protect against flooding, and improved air and water quality. [67]	Wants to increase accessibility of the Netherlands, via air and land. Is initiative taker of collaboration between NS and ProRail for HSR development. Invest in hyperloop to test feasibility and practicality of this new mode of transport. Collaborates with Ministry of Economic Affairs and Climate policy and subsidise the Hyperloop Development program together with 4,5 million euro. [68]Relevant for the implementation of hyperloop and expansion of HSR but are mainly important in the realisation phase of HPT and more elaborate HSR.
Ministry of Economic Affairs & Climate Policy (E&C)	Wants to make transport more sustainable in order to achieve set climate goals. Mainly important in the innovation and realisation phase	Is committed to creating an excellent entrepreneurial business climate, by creating the right conditions and giving entrepreneurs room to innovate and grow. This is done by paying attention to nature and the living environment and by encouraging cooperation between research institutes and businesses.[69]	Collaborates with the Ministry of infrastructure & water management and subsidise the Hyperloop Development program. together with 4,5 million euro. [70] Mainly needed in the realisation phase for the construction of an elaborate HSR and HPT network.
Ministry of the Interior and Kingdom Relations (I&K)	Important for exploitation phase	Formulate policies, prepare legislation and regulations and responsible for coordination, supervision and policy implementation. Wants to maintain good relations with other countries. [71]	Crucial player in policy making
Regional & local government bodies			
Province of Noord-Holland	Link Schiphol, APT, HSR and HPT	The main responsibilities and goals of the province are a sustainable economy, spatial development and water management, a vibrant countryside, preservation of nature and development of new natural areas, regional accessibility and public transport, sufficient employment	Province in which Schiphol is located, therefor involved in development taking place at Schiphol and interested in increasing the number of passengers travelling via Schiphol, without continuing to push the environmental limits of Schiphol. Collaborated with Hardt Hyperloop in an explorative study for HPT, now mainly involved in

[65] https://www.rijkshuisstijl.nl/over-de-rijkshuisstijl/missie-en-motto-rijksoverheid
[66] file:///Users/lottegoudswaard/Downloads/Wijziging+besluit+subsidie+Hyperloop+Development+Program.pdf
[67] https://www.government.nl/ministries/ministry-of-infrastructure-and-water-management
[68] https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/kamerstukken/2020/10/19/kamerbrief-ontwikkeling-van-de-hyperloop/kamerbrief-ontwikkeling-van-de-hyperloop.pdf
[69] https://www.government.nl/ministries/ministry-of-economic-affairs-and-climate-policy
[70] https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/kamerstukken/2020/10/19/kamerbrief-ontwikkeling-van-de-hyperloop/kamerbrief-ontwikkeling-van-de-hyperloop.pdf
[71] https://www.government.nl/ministries/ministry-of-the-interior-and-kingdom-relations

		and preservation and management of cultural heritage and preservation of monuments. [72]	hyperloop for freight transport. Not much power and interest
Province of Groningen	Invests in HPT,	Solve the challenges the province is facing together with its inhabitants, other governmental bodies, companies and social organisations and to redeem the opportunities in the area of quality of life, economy, greening, digitalisation and ecology.[73]	Contributes 3 million to Hyperloop Development Program and facilitates the test track of hyperloop.[74] Reason for doing so is and to enlarge regional development and the employment generated in the province as a consequence of the hyperloop test track and further development. Facilitates the innovation phase of hyperloop. Not much power.
Metropolitan Area Amsterdam (MRA)	Less important than Municipality of Haarlemmermeer	Maintain its position of economically strongest region in Europe and deal with the challenges in the area of economy and sustainability.[75]	Strengthen the international competitiveness of the region and make the corridor of Schiphol- Amsterdam the international entrance of the Netherlands[76]
Municipality of Haarlemmermeer	Municipality in which AAS is located: APT, HSR, HPT	Strengthen and expand high-quality living-, working-learning and residential environment by focussing on circular innovations and knowledge development. [77] Maintaining quality of life while adding new infrastructure.	Balance further growth of Schiphol and liveability of the area. Become the best airport region on sustainable aspects.[78]
Municipality of Amsterdam	Wants to maximize welfare and the attractiveness of Amsterdam	Improve accessibility, quality of live, safety and attractiveness of Amsterdam. [79]	Meet the increasing need for mobility, while maintaining liveability of the city and prioritising public spaces. Reduce car usage largely and increase bike and public transport usage and focus on smart and sustainable, innovative modes of transport.[80]
Representatives of traveller			
Rover	Represent the interests of PT travellers in the Netherlands	Represent public transport travellers. Want good public transport as attractive alternative for car and plane. Aim is to have a society with comfortable, affordable, reliable and high-frequent public transport enabling people to travel faster and cheaper than when travelling by car. By doing so	Good public transport as alternative to car and plane[82]

[72] https://www.noord-holland.nl/Onderwerpen
[73] https://www.provinciegroningen.nl/fileadmin/user_upload/Documenten/Bestuur_en_organisatie/Missie_visie_en_kernwaarden_provincie_Groningen_4_juli_2019.pdf
[74] https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/kamerstukken/2020/10/19/kamerbrief-ontwikkeling-van-de-hyperloop/kamerbrief-ontwikkeling-van-de-hyperloop.pdf
[75] https://mraduurzaam.nl/doelstellingen/
[76] https://samenbouwenaanbereikbaarheid.nl/application/files/7515/4816/4824/ENTER_NL_Ambitie_en_urgentie.pdf
[77] https://haarlemmermeergemeente.nl/file/5352/download
[78] https://haarlemmermeergemeente.nl/file/15828/download
[79] https://www.amsterdam.nl/bestuur-organisatie/organisatie/
[80] https://assets.amsterdam.nl/publish/pages/865232/mobiliteitsaanpak_amsterdam_2030.pdf
[82] https://www.rover.nl/vereniging/over-rover

		society can continue to move while saving the environment.[81]	
ANWB	Stands for creating an accessible country for everyone	Wants to make mobility easier for people, remove obstacles and provide assistance where necessary. Active in the fields of mobility, road safety, holiday and day trips.[83]	Easily accessible mobility for everyone.
Travellers	Users of the system	Want good connectivity of the Netherlands with the rest of Europe in a cheap and fast way	Are the end-users and choose between the different modes. Are the ones determining the market shares of the different modes.
Other stakeholder			
Royal HaskoningDHV (RHDHV) (client)	Client	Wants to gain knowledge on the future of long-distance transport in Europe and in the potential of hyperloop as mode of transport.	Gain knowledge on the future travel demand of APT, HSR and HPT.

[81] https://www.rover.nl/vereniging/over-rover
[83] https://www.anwb.nl/over-anwb/doelstelling

Appendix N – Formal Chart

Among the different stakeholders, interrelations can be identified. These interrelations influence the impact stakeholders have on the design and on the way in which there should be dealt with the different stakeholders. A formal chart is constructed to provide an overview of these interrelations (*Figure 14)*.
This formal chart visualises the interrelations, interdependencies and hierarchical structures present among the stakeholders.

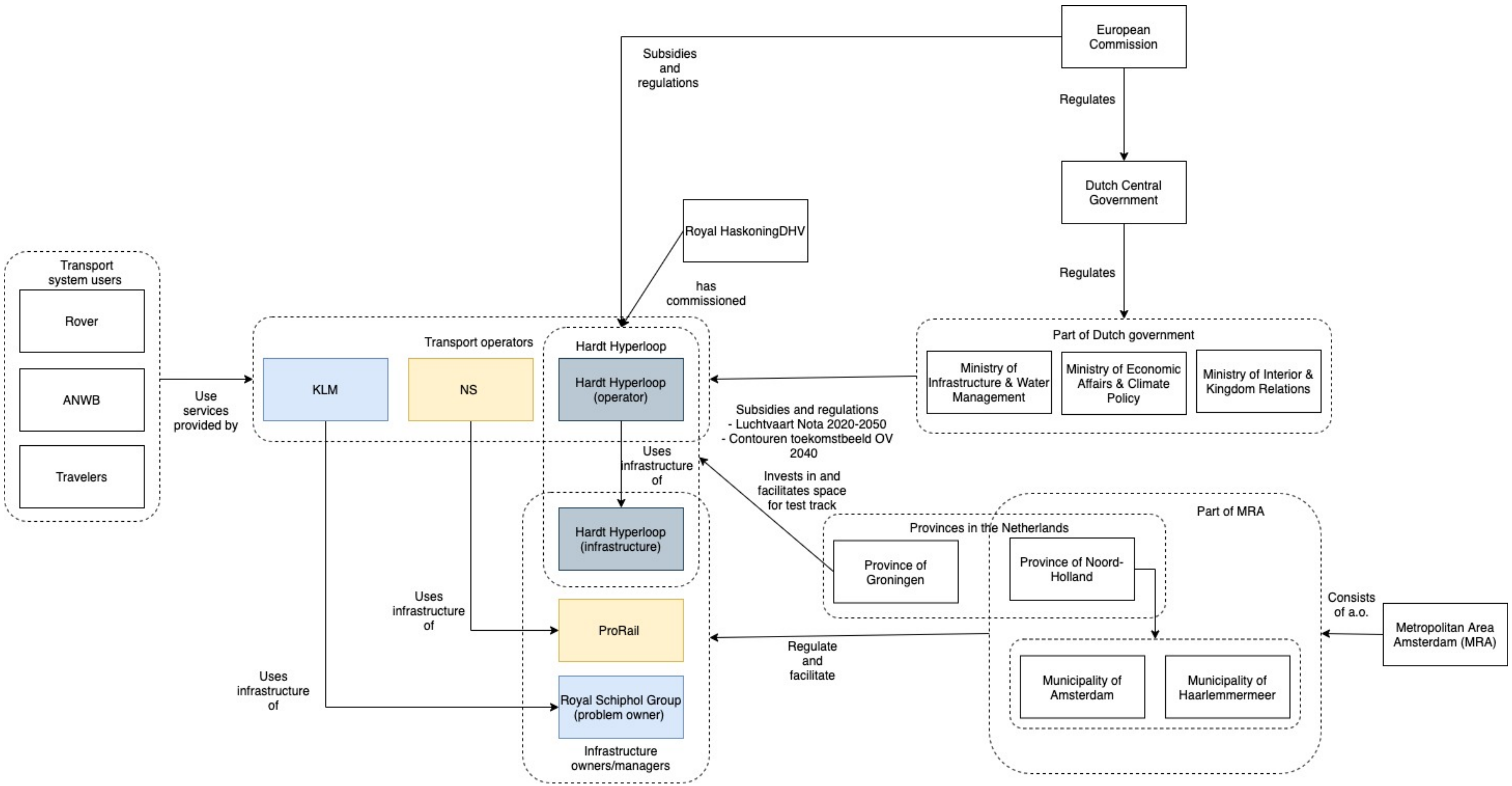


Figure 15: Formal chart

Appendix O – Version 1 of the hyperloop introduction of the SP experiment

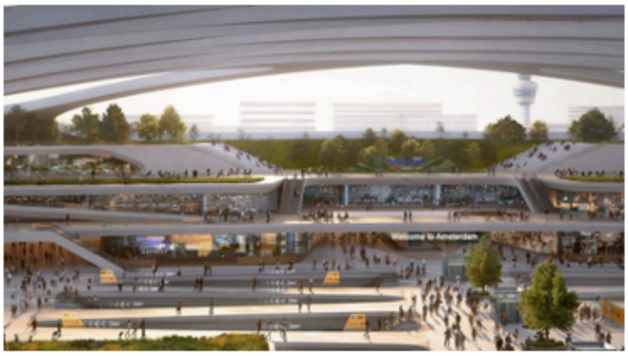
Hyperloop is een vervoermiddel dat in ontwikkeling is en zich in de testfase bevindt. Bij hyperloop worden voertuigen door een vacuümbuis verplaatst. Deze voertuigen worden pods genoemd en hebben een capaciteit van 60 mensen. Hyperloop wordt door middel van magneten aangedreven. Op de buitenkant van de buis zitten zonnepanelen die zorgen voor de energie die nodig is. In de pods is geen bestuurder aanwezig, wel worden deze op afstand door mensen gecontroleerd. Als u in een hyperloop zit, kunt u niet naar buiten kijken. Aan de binnenkant van het voertuig worden beelden weergegeven die sterk op de omgeving lijken waarin u zich op dat moment bevindt. De stoelen en de indeling in een pod zijn vergelijkbaar met een trein. U kunt bij hyperloop de volgende aannames doen:

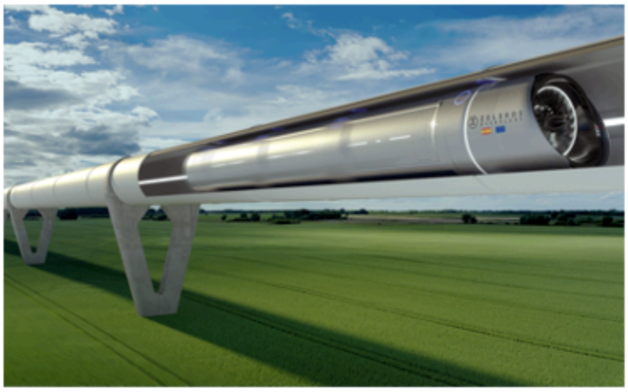
- U reist 2e klasse
- Hyperloop heeft een snelheid van ongeveer 700 km/uur

Appendix P – Version 2 of the hyperloop introduction of the SP experiment

Hyperloop is een vervoermiddel dat in ontwikkeling is en zich in de testfase bevindt. Bij hyperloop worden voertuigen door een vacuümbuis verplaatst. Deze voertuigen worden pods genoemd en hebben een capaciteit van 60 mensen. Hyperloop wordt door middel van magneten aangedreven. Op de buitenkant van de buis zitten zonnepanelen die zorgen voor de energie die nodig is. In de pods is geen bestuurder aanwezig, wel worden deze op afstand door mensen gecontroleerd. Als u in een hyperloop zit, kunt u niet naar buiten kijken. Aan de binnenkant van het voertuig worden beelden weergegeven die sterk op de omgeving lijken waarin u zich op dat moment bevindt. De stoelen en de indeling in een pod zijn vergelijkbaar met een trein. U kunt bij hyperloop de volgende aannames doen:

- U reist 2e klasse
- Hyperloop heeft een snelheid van ongeveer 700 km/uur



Appendix Q – Ngene syntax

In this appendix the Ngene code that was used to generate the choice sets is provided.

```
 design
;alts = APT , HSR , HPT
;rows = 36
;block = 4
;orth = sim
;model:
U(APT) = B_TC_APT * TC_APT[35,110,185] + B_IVT1_APT * IVT1_APT[0.45,1.05,1.25]
+ B_ET_APT * ET_APT[0.05,0.25,0.45] +B_BH_APT * BH_APT[0,1]/
U(HSR) = B_TC_HSR * TC_HSR[35,110,185] + B_IVT_HSR * IVT_HSR[3.15,3.45,4.15]
+ B_ET_HSR * ET_HSR[0.05,0.25,0.45] + B_BH_HSR * BH_HSR[0,1]/
U(HPT) = B_TC_HPT * TC_HPT[35,110,185] + B_IVT1_HPT * IVT1_HPT[0.45,1.05,1.25]
+ B_WT * WT[0.15,0.35,0.55] + B_ET_HPT * ET_HPT[0.05,0.25,0.45] + B_BH_HPT * BH_HPT[0,1]
$
```

Appendix R – Survey

In this Appendix the final survey can be found. The choice sets of only one of the four blocks is included.

Beste Deelnemer,

Deze enquête is onderdeel van mijn afstudeeronderzoek aan de Technische Universiteit Delft. Dit onderzoek wordt uitgevoerd in samenwerking met Royal HaskoningDHV en Hardt Hyperloop. Het doel van mijn onderzoek is inzicht krijgen in de keuzes die reizigers maken tussen verschillende vervoermiddelen als zij reizen binnen Europa. Het gaat om reizen met afstanden van rond de 500 km. Hierbij kunt u bijvoorbeeld denken aan reizen van Amsterdam naar Parijs, Londen of Frankfurt. In mijn onderzoek kijk ik naar drie verschillende vervoermiddelen: het vliegtuig, de hogesnelheidstrein en een nieuw vervoermiddel dat nog in ontwikkeling is, de hyperloop. Toelichting op de verschillende vervoermiddelen volgt.

Het invullen van de enquête duurt ongeveer 10 tot 15 minuten. De enquête is anoniem. Er wordt zorgvuldig en vertrouwelijk met uw antwoorden en persoonsgegevens omgegaan. Door het invullen van de enquête geeft u toestemming voor het gebruik van de data voor wetenschappelijke doeleinden en voor het opslaan van de resultaten in de TU Delft database. Op elk moment in de enquête kunt u stoppen zonder hiervoor een reden te geven.

U kunt de enquête het beste op een computer of laptop invullen.

Alvast veel dank voor uw deelname aan mijn onderzoek. Mocht u vragen of opmerkingen hebben, dan kunt u mijn een e-mail sturen (lotte.goudswaard@rhdhv.com).

Met vriendelijke groet,

Lotte Goudswaard

Royal HaskoningDHV Enhancing Society Together

HARDT HYPERLOOP

TU Delft

Hoe bent u bij dit onderzoek terecht gekomen?

- Via via
- Panel
- Dat weet ik niet

→

Ik verzoek u om onderstaande uitleg goed te lezen. Na de uitleg volgen een aantal vragen. U krijgt verschillende situaties voorgelegd waarin u wordt gevraagd een keuze te maken tussen de gegeven opties.

In dit onderzoek worden drie vervoermiddelen meegenomen: het vliegtuig, de hogesnelheidstrein en de hyperloop.

Voor alle drie de vervoermiddelen kunt u de volgende aannames doen:

- **U vertrekt altijd vanaf Amsterdam Airport Schiphol naar een bestemming binnen Europa**
- **De vervoermiddelen vertrekken op het moment van de dag dat u het best uitkomt. Met vertrektijden hoeft u dus geen rekening te houden**
- **U kunt tickets van tevoren online boeken of voor vertrek op het station of de luchthaven kopen**

Bij het *vliegtuig* kunt u uitgaan van de volgende aannames:

- **U vliegt Economy class**
- **De snelheid van een vliegtuig is ongeveer 850 km/uur**

Heeft u in de afgelopen 5 jaar gevlogen vanaf Amsterdam Airport Schiphol?

Ja

Nee

← →

Hoe vaak reist u met ingecheckte bagage als u gebruik maakt van het vliegtuig?

Altijd

Meestal

Ongeveer even vaak met als zonder

Bijna nooit

Nooit

Welk vervoermiddel gebruikt u meestal om naar Schiphol te reizen?

De auto

Gebracht met de auto

De trein

Andere vormen van openbaar vervoer dan de trein

Anders, namelijk

Bij de ***hogesnelheidstrein*** **kunt u van de volgende aannames uitgaan:**

- **U reist 2e klasse**
- **De snelheid van een hogesnelheidstrein is ongeveer 280 km/uur**
- **De hogesnelheidstrein gebruikt groene energie**

Heeft u afgelopen 5 jaar gereisd in de 2e klasse van de hogesnelheidstrein voor reizen binnen Europa?

Ja

Nee

Als u normaal gesproken met hogesnelheidstrein reist, welk station kiest u dan doorgaans om op te stappen?

Schiphol

Amsterdam Centraal

Rotterdam Centraal

Utrecht Centraal

Arnhem

Breda

Geen voorkeur

Hyperloop **is een vervoermiddel dat in ontwikkeling is en zich in de testfase bevindt. Bij hyperloop worden voertuigen door een vacuümbuis verplaatst. Deze voertuigen worden pods genoemd en hebben een capaciteit van 60 mensen. Hyperloop wordt door middel van magneten aangedreven. Op de buitenkant van de buis zitten zonnepanelen die zorgen voor de energie die nodig is. In de pods is geen bestuurder aanwezig, wel worden deze op afstand door mensen gecontroleerd. Als u in een hyperloop zit, kunt u niet naar buiten kijken. Aan de binnenkant van het voertuig worden beelden weergegeven die sterk op de omgeving lijken waarin u zich op dat moment bevindt. De stoelen en de indeling in een pod zijn vergelijkbaar met een trein. U kunt bij hyperloop de volgende aannames doen:**

- **U reist 2e klasse**
- **Hyperloop heeft een snelheid van ongeveer 700 km/uur**

Had u voor dit onderzoek van hyperloop gehoord?

Ja, ik had al een goed beeld van wat hyperloop is

Ja, ik had wel eens over hyperloop gehoord en wist ongeveer wat het is

Ja, ik had wel eens over hyperloop gehoord, maar wist niet precies wat het is

Nee, voor dit onderzoek had ik nog nooit van hyperloop gehoord

→

In het volgende onderdeel worden 9 vragen gesteld waarin u wordt gevraagd een keuze te maken tussen het vliegtuig, de hogesnelheidstrein en de hyperloop. De specifieke kenmerken van de alternatieven zullen steeds variëren.

U mag ervan uit gaan dat de hyperloop al volledig is gebouwd en in gebruik is. Het gaat steeds om reizen van ongeveer 500 kilometer, binnen Europa. Beantwoord de vragen in het nu (2021), maar ga ervan uit dat er geen Coronapandemie is.

Maakt u weleens zakelijke reizen?

Ja

Nee

←

→

In figuur 1 zijn de verschillende onderdelen van de reis weergegeven. In figuur 2 ziet u een voorbeeld van een keuzesituatie.

Figuur 1: Onderdelen van de reis

Figuur 2: Voorbeeld keuzesituatie

	Vliegtuig	Hogesnel-heidstrein	Hyperloop
Reiskosten	€185	€110	€35
Tijd in hoofdvervoer (uu:mm)	01:05	03:45	01:25
Wachttijd (uu:mm)	*02:00*	*00:15*	00:35
Tijd na transport (uu:mm)	00:55	00:05	00:30
Bagage	Bagage is ingecheckt tijdens het hoofdvervoer	Bagage kan **niet** worden ingecheckt	Bagage is ingecheckt tijdens het hoofdvervoer

De situaties die u krijgt voorgelegd verschillen op de volgende punten:

- **Reiskosten:** de kosten voor de gehele reis, van uw huis tot uw eindbestemming. De kosten van voor-en natransport zijn hierin dus ook meegenomen.
- **Tijd in hoofdvervoer:** de tijd die u in het vliegtuig, de hogesnelheidstrein of de hyperloop zit vanaf Amsterdam Airport Schiphol.
- **Wachttijd:** de tijd die u moet wachten voor of tussen de verschillende onderdelen van uw reis door bijvoorbeeld veiligheidscontroles of tijd die u van tevoren aanwezig bent op het station of op de luchthaven. Wachttijd wordt alleen voor hyperloop gevarieerd. Voor het vliegtuig is dit steeds 2 uur, voor de hogesnelheidstrein 15 minuten.
- **Tijd na transport:** de tijd om van het voertuig naar uw eindbestemming te komen. Denk hierbij aan tijd om bagage op te halen, tijd om van het voertuig naar de uitgang van de luchthaven of het station te komen, en de reistijd vanaf de luchthaven of het station naar uw eindbestemming.
- **Bagage:** voor de manier van bagage-afhandeling tijdens het hoofdvervoer zijn twee verschillende opties. Optie 1: uw bagage is ingecheckt. Wel heeft u de mogelijkheid om (kleine) handbagage mee te nemen. Optie 2: u kunt *geen* bagage inchecken. U heeft gedurende de gehele reis al uw bagage bij u.

Wilt u alle bovenstaande informatie kunnen bekijken tijdens het invullen van de enquête? Klik dan HIER

Er volgen nu 9 keuzesituaties.

←

→

Keuze 1/9

	Vliegtuig	Hogesnel-heidstrein	Hyperloop
Reiskosten	€35	€185	€185
Tijd in hoofdvervoer (uu:mm)	01:25	04:15	00:45
Wachttijd (uu:mm)	*02:00*	*00:15*	00:15
Tijd na transport (uu:mm)	00:30	00:05	00:30
Bagage	Bagage kan **niet** worden ingecheckt	Bagage kan **niet** worden ingecheckt	Bagage kan **niet** worden ingecheckt

Welk alternatief kiest u voor uw reis binnen Europa?

Vliegtuig

Hogesnelheidstrein

Hyperloop

Keuze 2/9

	Vliegtuig	**Hogesnel-heidstrein**	**Hyperloop**
Reiskosten	€110	€185	€35
Tijd in hoofdvervoer (uu:mm)	01:25	03:15	01:25
Wachttijd (uu:mm)	*02:00*	*00:15*	00:35
Tijd na transport (uu:mm)	00:30	00:55	00:05
Bagage	Bagage is ingecheckt tijdens het hoofdvervoer	Bagage kan **niet** worden ingecheckt	Bagage is ingecheckt tijdens het hoofdvervoer

Welk alternatief kiest u voor uw reis binnen Europa?

Vliegtuig

Hogesnelheidstrein

Hyperloop

Keuze 3/9

	Vliegtuig	**Hogesnel-heidstrein**	**Hyperloop**
Reiskosten	€35	€110	€110
Tijd in hoofdvervoer (uu:mm)	01:25	03:15	00:45
Wachttijd (uu:mm)	*02:00*	*00:15*	00:55
Tijd na transport (uu:mm)	00:55	00:30	00:55
Bagage	Bagage is ingecheckt tijdens het hoofdvervoer	Bagage is ingecheckt tijdens het hoofdvervoer	Bagage kan **niet** worden ingecheckt

Welk alternatief kiest u voor uw reis binnen Europa?

Vliegtuig

Hogesnelheidstrein

Hyperloop

Keuze 4/9

	Vliegtuig	Hogesnel-heidstrein	Hyperloop
Reiskosten	€110	€35	€35
Tijd in hoofdvervoer (uu:mm)	00:45	03:15	01:05
Wachttijd (uu:mm)	*02:00*	*00:15*	00:35
Tijd na transport (uu:mm)	00:55	00:30	00:55
Bagage	Bagage kan **niet** worden ingecheckt	Bagage kan **niet** worden ingecheckt	Bagage kan **niet** worden ingecheckt

Welk alternatief kiest u voor uw reis binnen Europa?

Vliegtuig

Hogesnelheidstrein

Hyperloop

Keuze 5/9

	Vliegtuig	Hogesnel-heidstrein	Hyperloop
Reiskosten	€185	€35	€110
Tijd in hoofdvervoer (uu:mm)	00:45	03:45	00:45
Wachttijd (uu:mm)	*02:00*	*00:15*	00:55
Tijd na transport (uu:mm)	00:55	00:05	00:30
Bagage	Bagage is ingecheckt tijdens het hoofdvervoer	Bagage kan **niet** worden ingecheckt	Bagage is ingecheckt tijdens het hoofdvervoer

Welk alternatief kiest u voor uw reis binnen Europa?

Vliegtuig

Hogesnelheidstrein

Hyperloop

Keuze 6/9

	Vliegtuig	Hogesnel-heidstrein	Hyperloop
Reiskosten	€110	€185	€185
Tijd in hoofdvervoer (uu:mm)	00:45	03:45	01:05
Wachttijd (uu:mm)	*02:00*	*00:15*	00:15
Tijd na transport (uu:mm)	00:05	00:55	00:05
Bagage	Bagage is ingecheckt tijdens het hoofdvervoer	Bagage is ingecheckt tijdens het hoofdvervoer	Bagage kan **niet** worden ingecheckt

Welk alternatief kiest u voor uw reis binnen Europa?

Vliegtuig

Hogesnelheidstrein

Hyperloop

Keuze 7/9

	Vliegtuig	Hogesnel-heidstrein	Hyperloop
Reiskosten	€185	€110	€110
Tijd in hoofdvervoer (uu:mm)	01:05	03:45	01:25
Wachttijd (uu:mm)	*02:00*	*00:15*	00:55
Tijd na transport (uu:mm)	00:05	00:55	00:05
Bagage	Bagage kan **niet** worden ingecheckt	Bagage kan **niet** worden ingecheckt	Bagage kan **niet** worden ingecheckt

Welk alternatief kiest u voor uw reis binnen Europa?

Vliegtuig

Hogesnelheidstrein

Hyperloop

Keuze 8/9

	Vliegtuig	Hogesnel-heidstrein	Hyperloop
Reiskosten	€35	€110	€185
Tijd in hoofdvervoer (uu:mm)	01:05	04:15	01:05
Wachttijd (uu:mm)	*02:00*	*00:15*	00:15
Tijd na transport (uu:mm)	00:05	00:30	00:55
Bagage	Bagage is ingecheckt tijdens het hoofdvervoer	Bagage kan **niet** worden ingecheckt	Bagage is ingecheckt tijdens het hoofdvervoer

Welk alternatief kiest u voor uw reis binnen Europa?

Vliegtuig

Hogesnelheidstrein

Hyperloop

Keuze 9/9

	Vliegtuig	Hogesnel-heidstrein	Hyperloop
Reiskosten	€185	€35	€35
Tijd in hoofdvervoer (uu:mm)	01:05	04:15	01:25
Wachttijd (uu:mm)	*02:00*	*00:15*	00:35
Tijd na transport (uu:mm)	00:30	00:05	00:30
Bagage	Bagage is ingecheckt tijdens het hoofdvervoer	Bagage is ingecheckt tijdens het hoofdvervoer	Bagage kan **niet** worden ingecheckt

Welk alternatief kiest u voor uw reis binnen Europa?

Vliegtuig

Hogesnelheidstrein

Hyperloop

Bij de volgende vragen gaat het om het beeld dat u van hyperloop, hogesnelheidstrein en vliegtuig heeft. Wilt u op een schaal van 1 tot 5 aangeven wat volgens u het meest van toepassing is?

Comfort

	Zeer oncomfortabel				Zeer comfortabel
	1	2	3	4	5
Hogesnelheidstrein	O	O	O	O	O
Hyperloop	O	O	O	O	O
Vliegtuig	O	O	O	O	O

Veiligheid

	Zeer onveilig				Zeer veilig
	1	2	3	4	5
Hogesnelheidstrein	O	O	O	O	O
Hyperloop	O	O	O	O	O
Vliegtuig	O	O	O	O	O

Milieuvriendelijkheid

	Zeer milieu-onvriendelijk				Zeer milieuvriendelijk
	1	2	3	4	5
Hogesnelheidstrein	O	O	O	O	O
Hyperloop	O	O	O	O	O
Vliegtuig	O	O	O	O	O

Comfort om te werken tijdens de reis

	Zeer laag werkcomfort				Zeer hoog werkcomfort
	1	2	3	4	5
Hogesnelheidstrein	O	O	O	O	O
Hyperloop	O	O	O	O	O
Vliegtuig	O	O	O	O	O

Beleving van de reis

	Zeer onprettige beleving				Zeer prettige beleving
	1	2	3	4	5
Hogesnelheidstrein	O	O	O	O	O
Hyperloop	O	O	O	O	O
Vliegtuig	O	O	O	O	O

Frequentie

	Zeer lage frequentie				Zeer hoge frequentie
	1	2	3	4	5
Hogesnelheidstrein	O	O	O	O	O
Hyperloop	O	O	O	O	O
Vliegtuig	O	O	O	O	O

Geluid van het voertuig tijdens de reis

	Zeer veel geluid				Zeer weinig geluid
	1	2	3	4	5
Hogesnelheidstrein	O	O	O	O	O
Hyperloop	O	O	O	O	O
Vliegtuig	O	O	O	O	O

Bereikbaarheid van station/luchthaven

	Zeer slecht bereikbaar				Zeer goed bereikbaar
	1	2	3	4	5
Hogesnelheidstrein	O	O	O	O	O
Hyperloop	O	O	O	O	O
Vliegtuig	O	O	O	O	O

Informatievoorziening tijdens de reis

	Zeer slechte informatievoorziening				Zeer goede informatievoorziening
	1	2	3	4	5
Hogesnelheidstrein	O	O	O	O	O
Hyperloop	O	O	O	O	O
Vliegtuig	O	O	O	O	O

Informatievoorziening op stations

	Zeer slechte informatievoorziening				Zeer goede informatievoorziening
	1	2	3	4	5
Hogesnelheidstrein	O	O	O	O	O
Hyperloop	O	O	O	O	O
Vliegtuig	O	O	O	O	O

Manier van ticket boeken

	Zeer gebruikers-onvriendelijk				Zeer gebruikersvriendelijk
	1	2	3	4	5
Hogesnelheidstrein	O	O	O	O	O
Hyperloop	O	O	O	O	O
Vliegtuig	O	O	O	O	O

Wat is uw geslacht?

- Vrouw
- Man
- Anders

Wat is uw geboortejaar?

____

Wat is het hoogste opleidingsniveau dat u heeft afgerond?

- Basisschool of geen diploma
- Vmbo
- Havo
- VWO
- MBO
- HBO
- WO-Bachelor
- WO-Master
- PhD

Wat is uw (persoonlijke) bruto jaarinkomen?

- Minder dan €10.000
- €10.000 - €20.000
- €20.000 - €30.000
- €30.000 - €40.000
- €40.000 - €50.000
- €50.000 - €60.000
- €60.000- €70.000
- €70.000 - €80.000
- €80.000 - €90.000
- €90.000 - €100.000
- €100.000 - €200.000
- Meer dan €200.000
- Dat zeg ik liever niet

Welke werksituatie is het meest op u van toepassing?

- Geen betaald werk
- Student (zowel met als zonder bijbaan)
- Betaald werk tot 20 uur per week
- Betaald werk voor 20 tot 40 uur per week
- Betaald werk voor 40 uur per week of meer
- Ik ben met pensioen
- Anders

Wat zijn de 4 cijfers van uw postcode?

Heeft u de inleidende tekst van dit onderzoek gelezen?

- Nee, helemaal niet gelezen
- Alleen delen vluchtig gelezen
- Alles vluchtig gelezen
- Ja, alles aandachtig gelezen

Heeft u het gevoel dat u een volledig beeld heeft van hyperloop?

Helemaal niet volledig	Niet echt volledig	Niet echt onvolledig maar ook niet volledig	Behooorlijk volledig	Helemaal volledig

Hoe vond u de uitleg over hyperloop?

Heel onduidelijk	Redelijk onduidelijk	Niet heel onduidelijk, maar ook niet heel duidelijk	Duidelijk	Heel duidelijk

De volgende vragen gaan over de enquête zelf.

Hoe vond u het niveau deze enquête?

Heel ingewikkeld	Ingewikkeld	Niet ingewikkeld, maar ook niet gemakkelijk	Gemakkelijk	Heel gemakkelijk

Hoe vond u het invullen van deze enquête?

Helemaal niet leuk	Niet echt leuk	Prima	Leuk	Heel leuk

Hoe vond u het tijdsbeslag van deze enquête?

Heel tijdrovend	Tijdrovend	Redelijk tijdrovend	Niet echt tijdrovend	Niet tijdrovend

Welke informatie heeft u in deze enquête gekregen over de manier van aandrijven van hyperloop?

- Dit gebeurt door magneten
- Dit gebeurt door elektriciteit uit bovenleidingen, zoals bij een trein
- Dit gebeurt door windenergie
- Weet ik niet

Kunt u tijdens het reizen met een hyperloop naar buiten kijken?

- Ja, maar alleen door het dak
- Ja, je kan door ramen aan de zijkant naar buiten kijken
- Nee, je kan niet naar buiten kijken, maar er worden wel beelden van de omgeving weergegeven in het voertuig
- Weet ik niet

Heeft u nog vragen of opmerkingen over deze enquête of over de gestelde vragen?

←

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Appendix S – Factor analysis

In this appendix the results of the factor analysis that has been conducted, in order to analyse if perceptions questions could be combined intro factors. For HSR and HPT separate factor analysis have been carried out. Factor analysis seeks to analyse shared variance among variables, in order to explain correlations. The extraction method of Principal Axis Factoring was applied and Varimax rotation was used to come to a better solution. New factors are created by taking the mean value of the perceptions that are combined into the given factor. In *Figure 15* the rotated factor matrix for HSR is presented, in *Figure 16* the rotated factor matrix for HPT is given. The value of 0.50 for factor loadings is used as guideline for combining a factor. If combining the perceptions together seems logical is also taken into consideration.

Rotated Factor Matrix[a]

	Factor			
	1	2	3	4
HSR_InfoStat	,818			
HSR_InfroReis	,652			
HSR_Boek	,553			
HSR_Bereik	,452		,450	
HSR_Werk		,634		
HSR_Comf		,564		
HSR_Belev		,547		
HSR_Snelh		,314		
HSR_Milieu				
HSR_Freq			,555	
HSR_Betr			,482	
HSR_Geluid			,425	
HSR_Veilig				,821
HSR_GeWeilig	,301		,356	,469

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

Figure 16: Rotated Factor Matrix HSR

The first factor indicated shared variance among information provided at the station, information available during the trip and the ease of booking a ticket for HSR. This factor is called HSR Information provision. The second factor can be labelled as trip comfort. General comfort, the comfort to work during the trip and travel experience are combined in this factor. Lastly, safety and feeling of safety are also combined into one factor, called overall safety HSR. Feeling of safety does not load above 0,50 but is very close and combining these two perceptions seems logical to do.

Rotated Factor Matrix[a]

	Factor 1	2	3	4
HPT_InfoStat	,837			
HPT_InfoReis	,730			
HPT_Boek	,598			
HPT_Bereik	,476			
HPT_Veilig		,807		,316
HPT_GevVeilig		,569	,479	
HPT_Freq			,496	
HPT_Betr			,431	
HPT_Geluid			,377	
HPT_Milieu				
HPT_Snelh				
HPT_Comf				,632
HPT_Werk				,617
HPT_Belev			,400	,411

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

Figure 17: Rotated Factor Matrix HPT

For HPT also a factor on information provision is formed, combining information provided at the station, information provided during the trip and ease of booking a ticket. The second factor is called overall safety HPT, combining safety and feeling of safety. The third factor is labelled trip comfort HPT. This factor is composed of comfort and comfort to work during the trip.

Appendix T – Apollo R script MNL model

```
### Clear memory
rm(list = ls())

### Load Apollo library
library(apollo)

### Initialise code
apollo_initialise()

### Set core controls
apollo_control = list(
  modelName  ="MNL_final_all",
  modelDescr ="MNL_final_all",
  indivID    ="ID"
)

#### LOAD DATA
database = read.delim("DATA_recode.dat",header=TRUE)


### Vector of parameters, including any that are kept fixed in estimation
apollo_beta=c(ASC_HSR      = 0,
              ASC_HPT      = 0,
              BETA_TC    = 0,
              BETA_IVT_APT = 0,
              BETA_IVT_HSR = 0,
              BETA_IVT_HPT = 0,
              BETA_WT      = 0,
              BETA_ET_APT  = 0,
              BETA_ET_HSR  = 0,
              BETA_ET_HPT  = 0,
              BETA_BH_APT  = 0,
              BETA_BH_HSR  = 0,
              BETA_BH_HPT  = 0,
              BETA_HSR_Comf = 0,
              BETA_HPT_Comf = 0,
              BETA_HSR_Safety = 0,
              BETA_HPT_Safety = 0,
              BETA_HSR_Freq = 0,
              BETA_HPT_Freq = 0,
              BETA_HPT_Exp = 0,
              BETA_HSR_Envir = 0,
              BETA_HPT_Envir = 0,
              BETA_HSR_Reliab = 0,
              BETA_HPT_Reliab = 0,
              BETA_HSR_Speed = 0,
              BETA_HPT_Speed = 0,
              BETA_HSR_Income = 0,
              BETA_HPT_Income = 0,
              BETA_HSR_Edu = 0,
              BETA_HPT_Edu = 0,
              BETA_HSR_Purpose = 0,
              BETA_HPT_Purpose = 0)
```

```r
### Vector with names (in quotes) of parameters to be kept fixed at their starting value in apollo_beta, use apollo_beta_fixed = c() if none
apollo_fixed = c()


#### GROUP AND VALIDATE INPUTS
apollo_inputs = apollo_validateInputs()


#### DEFINE MODEL AND LIKELIHOOD FUNCTION

apollo_probabilities=function(apollo_beta, apollo_inputs, functionality="estimate"){

  ### Attach inputs and detach after function exit
  apollo_attach(apollo_beta, apollo_inputs)
  on.exit(apollo_detach(apollo_beta, apollo_inputs))

  ### Create list of probabilities P
  P = list()

  ### Create alternative specific constants and coefficients using interaction with socio-demographics


  ### List of utilities: these must use the same names as in mnl_settings, order is irrelevant
  V = list()
  V = list()
  V[['APT']]  =           BETA_TC * TC_APT + BETA_IVT_APT * IVT_APT                 + BETA_ET_APT * ET_APT + BETA_BH_APT * BH_APT
  V[['HSR']]  = ASC_HSR + BETA_TC * TC_HSR + BETA_IVT_HSR * IVT_HSR                 + BETA_ET_HSR * ET_HSR + BETA_BH_HSR * BH_HSR
             + BETA_HSR_Comf * HSR_Comf_fact                                  +BETA_HSR_Safety * HSR_Safety_fact + BETA_HSR_Freq * HSR_Freq
             + BETA_HSR_Envir * HSR_Milieu + BETA_HSR_Reliab * HSR_Betr + BETA_HSR_Speed * HSR_Snelh + BETA_HSR_Income * Income
             + BETA_HSR_Edu * Edu + BETA_HSR_Purpose * Purpose
  V[['HPT']]  = ASC_HPT + BETA_TC * TC_HPT + BETA_IVT_HPT * IVT_HPT + BETA_WT * WT + BETA_ET_HPT * ET_HPT + BETA_BH_HPT * BH_HPT
              + BETA_HPT_Comf * HPT_Comf_fact_XX + BETA_HPT_Exp * HPT_Belev + BETA_HPT_Safety * HPT_Safety_fact + BETA_HPT_Freq * HPT_Freq
              + BETA_HPT_Envir * HPT_Milieu + BETA_HPT_Reliab * HPT_Betr + BETA_HPT_Speed * HPT_Snelh + BETA_HPT_Income * Income
              + BETA_HPT_Edu * Edu + BETA_HPT_Purpose * Purpose


  ### Define settings for MNL model component
  mnl_settings = list(
    alternatives  = c(APT=1, HSR=2, HPT=3),
    avail         = list(APT=1, HSR=1, HPT=1),
    choiceVar     = CHOICE,
    V             = V
  )

  ### Compute probabilities using MNL model
  P[['model']] = apollo_mnl(mnl_settings, functionality)

  ### Take product across observation for same individual
  P = apollo_panelProd(P, apollo_inputs, functionality)

  ### Prepare and return outputs of function
  P = apollo_prepareProb(P, apollo_inputs, functionality)
  return(P)
}


#### MODEL ESTIMATION
model = apollo_estimate(apollo_beta, apollo_fixed, apollo_probabilities, apollo_inputs)


#### MODEL OUTPUTS
apollo_modelOutput(model,modelOutput_settings=list(printPVal=TRUE))

apollo_saveOutput(model)
```

Appendix U – Apollo R script panel ML model

```
### Clear memory
rm(list = ls())

### Load Apollo library
library(apollo)

### Initialise code
apollo_initialise()

### Set core controls
apollo_control = list(
  modelName  ="ML_all_final",
  modelDescr ="ML_all_final",
  indivID    ="ID",
  mixing     = TRUE,
  nCores=5
)

#### LOAD DATA
database = read.delim("DATA_recode.dat",header=TRUE)

### Vector of parameters, including any that are kept fixed in estimation
apollo_beta=c(ASC_HSR      = 0,
              ASC_HPT      = 0,
              BETA_TC      = 0,
              BETA_IVT_APT = 0,
              BETA_IVT_HSR = 0,
              BETA_IVT_HPT = 0,
              BETA_WT      = 0,
              BETA_ET_APT  = 0,
              BETA_ET_HSR  = 0,
              BETA_ET_HPT  = 0,
              BETA_BH_APT  = 0,
              BETA_BH_HSR  = 0,
              BETA_BH_HPT  = 0,
              Sigma_land = 1,
              Sigma_exist = 0,
              BETA_HSR_Comf = 0,
              BETA_HPT_Comf = 0,
              BETA_HSR_Safety = 0,
              BETA_HPT_Safety = 0,
              BETA_HSR_Freq = 0,
              BETA_HPT_Freq = 0,
              BETA_HPT_Exp = 0,
              BETA_HSR_Envir = 0,
              BETA_HPT_Envir = 0,
              BETA_HSR_Reliab = 0,
              BETA_HPT_Reliab = 0,
              BETA_HSR_Speed = 0,
              BETA_HPT_Speed = 0,
              BETA_HSR_Income = 0,
              BETA_HPT_Income = 0,
              BETA_HSR_Edu = 0,
              BETA_HPT_Edu = 0,
              BETA_HSR_Purpose = 0,
              BETA_HPT_Purpose = 0)
```

```
### Vector with names (in quotes) of parameters to be kept fixed at their starting value in apollo_beta, use apollo_beta_fixed = c() if none
apollo_fixed = c()

### Set parameters for generating draws
apollo_draws = list(
  interDrawsType = "halton",
  interNDraws    = 400,
  interUnifDraws = c(),
  interNormDraws = c("draws"),
  intraDrawsType = "halton",
  intraNDraws    = 0,
  intraUnifDraws = c(),
  intraNormDraws = c()
)

### Create random parameters
apollo_randCoeff = function(apollo_beta, apollo_inputs){
  randcoeff = list()

  randcoeff[["EC_land_RND"]] =  Sigma_land * draws
  randcoeff[["EC_exist_RND"]] =  Sigma_exist * draws


  return(randcoeff)
}


#### GROUP AND VALIDATE INPUTS
apollo_inputs = apollo_validateInputs()


#### DEFINE MODEL AND LIKELIHOOD FUNCTION
apollo_probabilities=function(apollo_beta, apollo_inputs, functionality="estimate"){

  ### Attach inputs and detach after function exit
  apollo_attach(apollo_beta, apollo_inputs)
  on.exit(apollo_detach(apollo_beta, apollo_inputs))

  ### Create list of probabilities P
  P = list()

  ### List of utilities: these must use the same names as in mnl_settings, order is irrelevant
  V = list()
  V[['APT']]  =           BETA_TC * TC_APT + BETA_IVT_APT * IVT_APT                + BETA_ET_APT * ET_APT + BETA_BH_APT * BH_APT               + EC_exist_RND
  V[['HSR']]  = ASC_HSR + BETA_TC * TC_HSR + BETA_IVT_HSR * IVT_HSR                + BETA_ET_HSR * ET_HSR + BETA_BH_HSR * BH_HSR + EC_land_RND + EC_exist_RND
              + BETA_HSR_Comf * HSR_Comf_fact                             + BETA_HSR_Safety * HSR_Safety_fact + BETA_HSR_Freq * HSR_Freq
              + BETA_HSR_Envir * HSR_Milieu + BETA_HSR_Reliab * HSR_Betr + BETA_HSR_Speed * HSR_Snelh + BETA_HSR_Income * Income + BETA_HSR_Edu * Edu
              + BETA_HSR_Purpose * Purpose
  V[['HPT']]  = ASC_HPT + BETA_TC * TC_HPT + BETA_IVT_HPT * IVT_HPT + BETA_WT * WT + BETA_ET_HPT * ET_HPT + BETA_BH_HPT * BH_HPT + EC_land_RND
              + BETA_HPT_Comf * HPT_Comf_fact_XX + BETA_HPT_Exp * HPT_Belev + BETA_HPT_Safety * HPT_Safety_fact + BETA_HPT_Freq * HPT_Freq
              + BETA_HPT_Envir * HPT_Milieu + BETA_HPT_Reliab * HPT_Betr + BETA_HPT_Speed * HPT_Snelh + BETA_HPT_Income * Income + BETA_HPT_Edu * Edu
              + BETA_HPT_Purpose * Purpose
  ### Define settings for MNL model component
  mnl_settings = list(
    alternatives  = c(APT=1, HSR=2, HPT=3),
    avail         = list(APT=1, HSR=1, HPT=1),
    choiceVar     = CHOICE,
    V             = V
  )

  ### Compute probabilities using MNL model
  P[['model']] = apollo_mnl(mnl_settings, functionality)

  ### Take product across observation for same individual
  P = apollo_panelProd(P, apollo_inputs, functionality)

  ### Average across inter-individual draws
  P = apollo_avgInterDraws(P, apollo_inputs, functionality)

  ### Prepare and return outputs of function
  P = apollo_prepareProb(P, apollo_inputs, functionality)
  return(P)
}


#### MODEL ESTIMATION
model = apollo_estimate(apollo_beta, apollo_fixed,
                        apollo_probabilities, apollo_inputs, estimate_settings=list(hessianRoutine="maxLik"))


#### MODEL OUTPUTS
apollo_modelOutput(model,modelOutput_settings=list(printPVal=TRUE))

apollo_saveOutput(model)
```