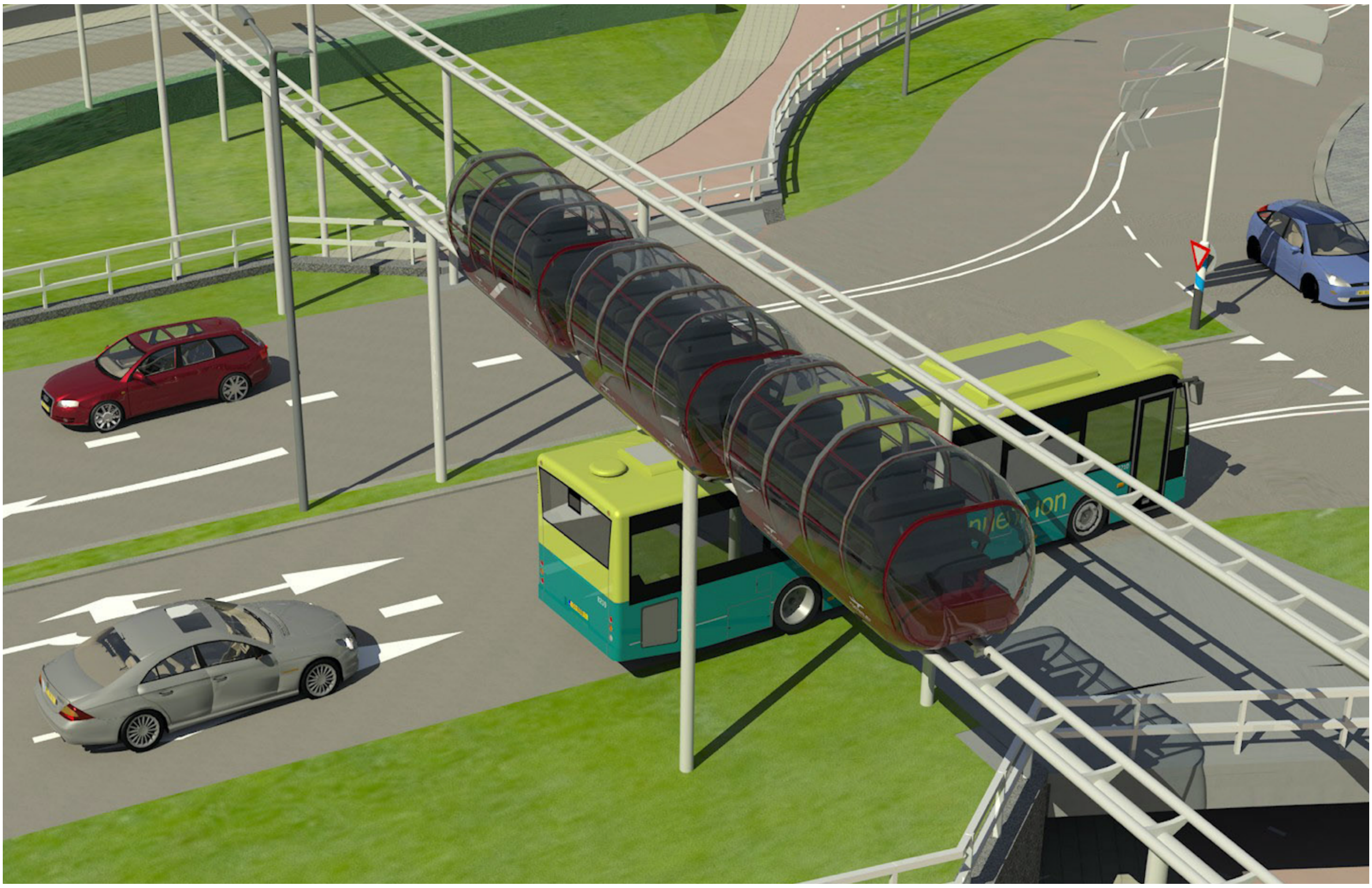


Feasibility study of the City Coaster

A transport innovation to improve the accessibility of

Rotterdam The Hague Airport

L.J.M. Meex

Master of Science Thesis

Feasibility study of the City Coaster

A transport innovation to improve the accessibility of Rotterdam – The Hague Airport

By

L.J.M. Meex

in partial fulfillment of the requirements for the degree of

Master of Science
in Transport, Infrastructure and Logistics

at Delft University of Technology

August 2017

Name:	L.J.M. (Luc) Meex
Student number:	4513738
E-mail:	l.j.m.meex@student.tudelft.nl

Thesis committee:	Prof. dr. Bert van Wee	TU Delft, Transport & Logistics (TPM)
	Dr. Jan Anne Annema	TU Delft, Transport & Logistics (TPM)
	Dr. ir. Gonçalo Correia	TU Delft, Transport & Planning (CiTG)
	Ing. Erik Jongenotter	Witteveen + Bos

Preface

This thesis is conducted as the last part of my Master of Science in Transport, Infrastructure and Logistics at Delft University of Technology and was carried out in cooperation with Witteveen+Bos.

I would like to thank first of all my company supervisor Erik Jongenotter for making this thesis possible and for his enthusiasm, vision and experience regarding the topic. I want to thank my colleagues at Witteveen+Bos for their collegiality and the pleasant working environment.

A big thank you goes to my thesis committee. Professor Bert van Wee for chairing the thesis committee, his feedback and his clear instructions. Jan Anne Annema to keep me on track and for his positive and motivating feedback. Gonçalo Correia for his input and his experience regarding the research topic.

Furthermore, I would also like to thank the stakeholders involved for their time regarding the interviews, Rotterdam – The Hague airport for making the passenger interviews possible, the experts consulted for their knowledge and the political decision makers for their information regarding decision making processes. Next to that I would like to thank Jeroen Rijsdijk for the use of the transport model of the municipality of Rotterdam.

Finally, I would like to thank my family and friends for their support in all possible ways.

Luc Meex
Den Haag, August 2017

Executive summary

Cities worldwide keep growing and expanding in the future. To remain accessible the city of the future needs creative, innovative and sustainable transport solutions. An example of such a system is the City Coaster. The City Coaster has electric, automated small vehicles on exclusive infrastructure, a rollercoaster track. The driverless vehicles of the City Coaster are suitable for six to eight passengers and will arrive on call of the passengers. Compared to conventional rail and light rail systems it seems lighter, more flexible and compact. Therefore, it has been investigated in this research if the City Coaster is interesting as alternative public transport mode. The first research question was:

"Under which conditions is the City Coaster feasible?"

The feasibility of the City Coaster has been analyzed according to the theoretical framework of Feitelson & Salomon (2004). According to Feitelson & Salomon, a transport innovation can only be adopted if the innovation is technical, social and political feasible. They developed a model which explains the actual adoption of a new system based on these three requirements.

Based on the analysis of the City Coaster, the usefulness of the theoretical framework has been evaluated for real world applications. Currently, multiple transport innovations are discussed worldwide. The feasibility of these innovations should also be analyzed before they can be implemented. It has been investigated to what extend the theoretical model provides information for decision makers. The second research question was therefore:

''To what extend is applying the model of Feitelson & Salomon useful in the decision-making process of transport innovations such as the City Coaster?"

Research relevance

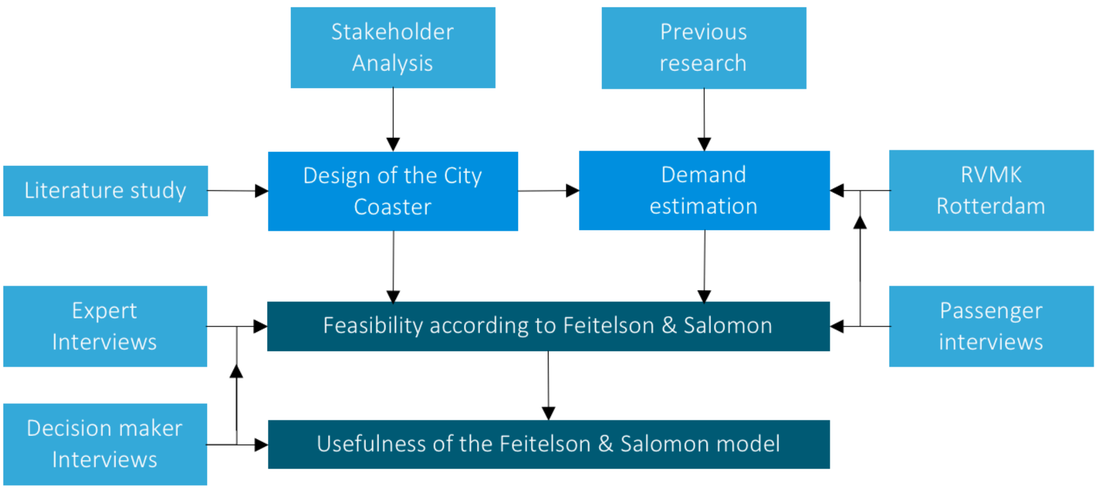
Current public transport modes by rail have high investment costs and maintenance is expensive. Recent research to the management, maintenance and replacement costs of tram, light rail and metro systems in Rotterdam, The Hague and Amsterdam shows that in the recent years the costs only increased (Mott MacDonald, 2017). The City Coaster, on the other hand, gives the impression that it is light and can be cheaper compared to conventional public transport which made it interesting to conduct research to. Next to that, the model used for the feasibility analysis has not been used often in practice before to analyze the ex-post feasibility of transport innovations, neither the usefulness of it has been discussed.

Case study

Part of the feasibility analysis according to Feitelson & Salomon is the distribution of benefits and costs. To determine the benefits and costs, a case study had to be chosen. For this case study, a design was made and the demand has been estimated. With the demand estimation and the design, the feasibility could be assessed. The case study chosen for this research is the connection between Rotterdam Central Station and Rotterdam The Hague Airport. This because the City of Rotterdam focusses on its architectural and innovative appearance in which the City Coaster could play a role, the accessibility of Rotterdam The Hague airport is a well-known, major issue for which the landside accessibility (other than private vehicles) has to be improved (Derksen et al., 2014) and because other companies investigated the business case to metro station Meijersplein already. Next to that, the connection to a national (and even international) train station seems most obvious. Currently it takes 23 minutes to travel from Central Station to the airport by bus and 20 minutes with bus and light rail (9292, 2017). A shorter travel time by public transport makes the use of public transport to and from the airport more attractive.

Research methods

As mentioned before, the distribution of benefits and costs is part of the social feasibility according to Feitelson & Salomon (2004). These benefits and costs are estimated based on a design and the demand estimation. The design could be made according to the engineering design cycle as defined by Dym, Little & Orwin (2004). First a stakeholder analysis was conducted in which the objectives and requirements for the City Coaster have been identified. Based on these requirements and further literature study a design could be made. The demand has been estimated based on airport data and OV-Chipcard data (Brands et al., 2015). Because with these sources no modal shift could be estimated, the transport model of the City of Rotterdam has been used and interviews were conducted at the airport. For the technical feasibility of the City Coaster, experts from the roller coaster and automotive industry were consulted. The political feasibility has been assessed by political decision makers. The total research method can be seen in the figure below. The results and conclusions will be discussed according to this method in the next sections.



Design of the City Coaster

Based on literature study it could be found that comparable systems as the City Coaster failed because of high investment costs. The costs are mainly determined by the track design. Therefore, the design should be as light as possible to save costs. The stakeholder analysis showed, among others, that the system should have a short waiting and travel time and it must be able to cope with the peak demand of the airport. The City Coaster should comply with the current safety regulations. Lastly, the stakeholder analysis showed that the City Coaster should have a viable business case.

The stakeholder analysis and literature study were input for the design of the City Coaster. The fleet size, waiting time, travel time and energy consumption could be estimated based on the design. These data were then used for the social feasibility in the cost benefit analysis.

Demand estimation

Different demand scenarios based on different sources were used to estimate the demand. First, the current use of public transport was estimated based on OV-Chipcard data. It was found that currently 610 passengers travel to and from the airport daily. Knowing that the current modal split of airport passengers is 12%, a public transport modal split of employees of 4.2% has been estimated. Next, the transport model of the municipality of Rotterdam was used to estimate a modal shift to the City Coaster. After adapting the model to the current situation and adding the City Coaster, a public transport modal split of 18.1% for the area could be estimated. Next to the transport model, passenger interviews at the airport were conducted to validate the modal split of 18.1%. The interviews were conducted face-to-face and online. The interviews showed a positive attitude towards the City Coaster. If the passengers would do as they say they would do according to the interview, the public transport modal split of Rotterdam – The Hague Airport would increase to 46.9% which is compared to other Dutch airports unrealistic. This excessive modal split could be explained because of a social desirability bias (Fisher, 1993). Taking into account a social desirability bias of 35% according to Steenkamp et al. (2009), the modal split for public transport would increase to 34.7%.

Feasibility according to Feitelson & Salomon

The model of Feitelson & Salomon describes that a transport innovation can only be adopted if the innovation is technical, social and political feasible. These requisites for adoption for the City Coaster will be described below.

Technical feasibility

According to experts from the roller coaster and the automotive industry the City Coaster is technically feasible. It is advised to use vehicle to vehicle technology (V2V) for the communication between the vehicles (C. van de Weijer, personal communication, May 15, 2017).

Social feasibility

Based on the interviews it was found that passengers have a positive attitude towards the City Coaster. Only 4% of the respondents does not want to use a City Coaster because of an aversion towards the system (afraid of heights, no driver in the vehicle). Compared to other transport modes (bus, tram, metro and train) the City Coaster is preferred above all other modes. The data obtained from the passenger interviews has been analyzed on logistic regression. It was found that younger people tend to use the City Coaster more than elder people, the same holds for business people compared to leisure travelers. People traveling with their partner would use the City Coaster less compared to someone traveling alone. Next to that, people traveling with friends or colleagues have a higher preference for the City Coaster compared to people traveling alone.

The cost-benefit analysis showed that the benefits exceed the costs in every scenario, except the scenario in which no modal shift occurs. It should be noted here that noise, nature and visual intrusion are not monetized in this cost-benefit analysis, these costs will affect the cost-benefit ratio negatively. Next to the cost-benefit analysis the business case for every demand scenario has been analyzed. It was found that subsidies are required if the airport passenger modal shift does not increase to 34.7%.

Political feasibility

As mentioned before, the political feasibility has been discussed with political decision makers in the field. The visual intrusion caused by the City Coaster track above street level will induce major opposition from residents living nearby according to the decision makers. Next to that, they doubt about the social value of this system if subsidies are required. If passengers can buy a flight ticket, they can also pay for their transport to the airport. Lastly, resistance is expected because this system will improve the accessibility of the airport. Generally speaking, it is expected that the City Coaster is not future proof if automated vehicles are able to transport people from A to B. On the other hand, by being restraint towards a solution to solve the current transport issues will not solve the current issues.

Conclusion

Based on the case study it was found that the City Coaster is a technical feasible system which is economically feasible in almost all demand scenarios. The feasibility is therefore not determined by the demand. The City Coaster is feasible under the conditions that the visual intrusion has to be eliminated by building the City Coaster underground, within buildings or shielded from public space.

Usefulness of the Feitelson & Salomon model

The research to the City Coaster gave insights in the usefulness of the political economy model of Feitelson & Salomon. The stakeholder analysis showed that the stakeholders were most interested in the business case and the technical feasibility of the City Coaster. Next to that, the model describes that a cost benefit analysis should be performed to analyze the economic feasibility. However, this cost benefit analysis does not provide insight in required subsidies. Therefore, an additional business case has to be performed.

Based on interviews with decision makers it was found that required information by the decision makers is covered by the model. The technical feasibility is according to the decision makers most important and the political feasibility is according to them hard to estimate. The factors identified by Feitelson & Salomon do indeed play a role in the political feasibility, however, there are probably more unidentified factors affecting the political feasibility which could not be identified by the decision makers. With the outcomes of the model of Feitelson & Salomon, the decision makers are able to make a decent decision regarding future transport innovations.

Recommendations

This research showed that the City Coaster is politically not feasible because of the visual intrusion caused by the track. It should be investigated how a City Coaster can be implemented in the City without causing visual intrusion. If an elevated track is not possible because of the opposition from inhabitants, it should be questioned why the vehicles should ride on a rail system. The vehicle design and automation of the system should be investigated further. With lighter vehicles, the construction can be lighter which will safe investment costs.

For future transport innovations, the model of Feitelson & Salomon (2004) is a useful tool to evaluate the feasibility. Based on the case study and according to the decision makers it has been found that the model provides useful information for the decision makers. Most information required by decision makers to make a decent decision is covered in the model. Which requisite for adoption must be investigated first, depends on the situation. If a transport innovation is a solution for a dedicated case, it is advised, based on the case study to the City Coaster, to analyze the political feasibility first. For a more general research to a transport innovation, it is advised by the decision makers to analyze the technical and social feasibility first before investigating the political feasibility. If subsidies are required it is advised to analyze the business case next to the cost benefit analysis.

Contents

Figures

Tables

1 Introduction

Cities worldwide keep growing and expanding in the future. To remain accessible the city of the future needs creative, innovative and sustainable transport solutions. Subsequently, the goal of the Dutch Government is that every person in the Netherlands should be able to travel fast, comfortable, reliable and affordable with public transport in 2040 (Ministerie van Infrastructuur en Milieu, 2016). The ministry states that innovations are needed to achieve this goal and to reduce the high costs of public transport. Currently, the government pays around 45% of the costs to make public transport possible (CROW, 2015). Next to that, recent research to the management, maintenance and replacement costs of tram, light rail and metro systems in Rotterdam, The Hague and Amsterdam shows that in the recent years these costs only increased (Mott MacDonald, 2017). Because of that, the budget left for investments only decreased the recent years.

In 2015, the Verkeersonderneming asked companies to think of innovative ideas to improve the accessibility of Rotterdam during the 'Rotterdamse Infrastructuur Uitdaging'. Witteveen+Bos, participated in this challenge with the idea of the City Coaster which can be seen in Figure 1-1. The City Coaster can be used as public transport system and has electric, automated small vehicles on exclusive infrastructure, a rollercoaster track. It is based on the proven technology of the automotive and roller coaster industry. The track and vehicles have a low height which makes it easy to install in small tunnels or passageways. This light and small design gives opportunities for routes which were not possible before. The driverless vehicles of the City Coaster are suitable for six to eight passengers and will arrive on call of the passengers. To prevent collisions, the vehicles will use proven technology from the automotive industry (e.g. adaptive cruise control). Unfortunately, the City Coaster did not fulfil the requirements of the challenge and Witteveen+Bos decided not to further participate.

Figure 1-1: The City Coaster, three automated vehicles on a roller coaster track

However, the idea of the City Coaster could still contribute to the goal of the ministry and be interesting as alternative public transport. Compared to conventional rail and light rail systems it seems lighter, more flexible and compact. The light design gives the impression that this system can be cheaper compared to other public transport systems (train, metro and tram). Therefore, it will be investigated in this research if the City Coaster is interesting as alternative public transport mode. This will be done based on a feasibility study.

Various innovation literature can be found to analyze the feasibility of the City Coaster. Geels (2002) defines a socio-technical system in which three levels are distinguished: technological niches, socio-technical regimes and landscape developments. With this system, a technological transition can be explained from a multilevel perspective in which these three levels interact. The system of Geels focusses mainly on how technological transitions come about, which makes it less suitable for the feasibility of the City Coaster.

Feitelson & Salomon (2004) developed a political economy model showing that a transport innovation can only be adopted if the innovation is technical, social and political feasible. Feitelson & Salomon state, based on innovations in the past, that future studies of innovations in the transportation field should pay more attention to politics and to the implications of decision making regarding innovations. Previous transport innovations (such as road pricing, light rail and telecommuting centers) failed because they did not fulfil the requirements set by the model of Feitelson & Salomon. However, based on literature search in the TU Delft library database, Google Scholar and Scopus, it has been found that the model of Feitelson & Salomon has not been applied often in practice to ex-ante evaluate transport innovations like the City Coaster. The model of Feitelson & Salomon explains the actual adoption of a new system based on three requirements which makes this model suitable for the feasibility of the City Coaster. Therefore, it has been chosen to use the model of Feitelson & Salomon to analyze the feasibility of the City Coaster.

Based on the analysis of the City Coaster, the usefulness of the theoretical framework will be evaluated for real world applications. Currently, multiple transport innovations are discussed worldwide. The feasibility of these innovations should also be analyzed before they can be implemented. It will be investigated to what extend the theoretical model provides information for decision makers.

1.1 Research relevance

The feasibility of the City Coaster has not been analyzed before, together with the impression that this innovation could be cheaper than conventional public transport, it is interesting to conduct research to. Next to that, this research will analyze the usefulness of the theoretical model of Feitelson & Salomon to evaluate the feasibility of transport innovations for real world applications. As mentioned before, the city of the future needs innovative transport solutions to remain accessible. This research will investigate, based on a case study on the City Coaster, to what extend this theoretical model is a useful tool in the decision-making process of such transport innovations. The model has not been used often in practice before to analyze the ex-post feasibility of innovations, neither the usefulness has been discussed. It should be noted here that the usefulness of the model will be based on a single case study to the City Coaster. Based on one case study, it cannot be concluded that transport innovations should use the model of Feitelson & Salomon. However, it can be found out to what extend the model provides information to decision makers.

1.2 Research objective and research questions

The objective of this research is to analyze the feasibility of the City Coaster and to evaluate the usefulness of the theoretical model of Feitelson & Salomon for real world applications. This will be done by using an in-depth case study in which the feasibility of the City Coaster will be analyzed. Therefore, the research questions of this research are:

"Under which conditions is the City Coaster feasible?"

and

''To what extend is applying the model of Feitelson & Salomon useful in the decision-making process of transport innovations such as the City Coaster?"

To answer the first research question, the following sub questions have been defined:

1. Which design considerations can be identified based on comparable systems such as the City Coaster?
2. What stakeholders are involved in the case study and what are their objectives?
3. What are the design requirements of the City Coaster?
4. What will be the expected demand for the City Coaster for the case study?
5. How does the design of the City Coaster look like?
6. To what extend is the City Coaster feasible according to the model of Feitelson & Salomon?

The second research question will be answered based on a reflection of the feasibility analysis of the City Coaster and the results of the analysis will be presented to decision makers in the field. They will be asked to assess the information provided by the model of Feitelson & Salomon. In this way, it can be found out if the model is useful in the decision-making process of transport innovations.

1.3 Research methods

As mentioned in the previous paragraph, the feasibility of the City Coaster will be analyzed according to the model of Feitelson & Salomon (2004). According to the model, a transport innovation can only be adopted if the innovation is technical, social and political feasible. They are dependent on interacting factors as can be seen in Figure 1-2. The political economy model of Feitelson & Salomon has not been applied to the City Coaster before. The interacting factors in case of the City Coaster are experts from the roller coaster and automotive industry, the interests of public transport companies and the advantages and disadvantages for the users of the City Coaster as well as for society compared to conventional public transport. The three requisites for adoption will be described below.

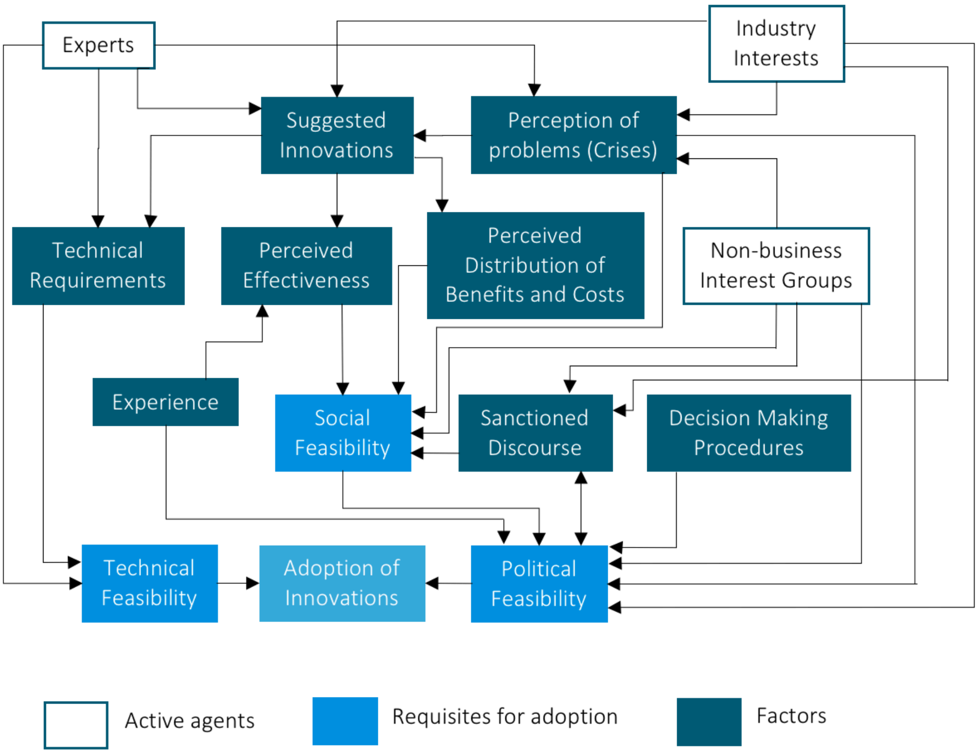


Figure 1-2: A political economy model of transport innovations. Source: Feitelson & Salomon (2004)

1.3.1 Technical feasibility

Before analyzing the social and political feasibility the transport innovation has to be technically feasible, it has to work technically. Technical requirements and expert judgement are the main input for the technical feasibility. The technical feasibility of the City Coaster will mostly be covered in the design process of the system. Based on interviews with experts, a technical feasible design will be made.

1.3.2 Political feasibility

Social acceptability is one factor involved in political feasibility, as politicians do take account of voter preferences. However, as politicians do need the support of interest groups, they try to accommodate specific demands of active lobbies, whether they represent industry interests or non-business interests. It can be said that politicians try to maximize the support they receive from interest groups, in a way that is socially acceptable. Moreover, decision makers try to solve the perceived problems, in a way that is social acceptable and that is justified with arguments that are within the present dominant discourse and so that they get more support from interest groups (Feitelson & Salomon, 2004).

For this research, the political feasibility will be analyzed by interviewing political decision makers to ask them whether they think the City Coaster will be politically feasible.

1.3.3 Social feasibility

The advantages and disadvantages for the users and society play the most important role in analyzing the social feasibility. Social feasibility is a function of public perception of problems and the perception of the effectiveness of the proposed innovation in addressing these problems (Feitelson & Salomon, 2004). The advantages and disadvantages for the users and society are monetized using a cost benefit analysis. It should be noted here that the innovation should not only pass a strict cost benefit criterion, the perceived distribution of costs and benefits has to be taken into consideration as well. The main literature that will be used for the cost-benefit analysis is the 'Algemene Leidraad voor maatschappelijke kosten-batenanalyse' (Romijn & Renes, 2013). This literature describes the requirements of a cost-benefit analysis according to the current insights regarding cost-benefit analyses and is broadly used for analyzing the cost-benefits of policies.

To assess the feasibility of the City Coaster as innovative transport system and to investigate the usefulness of the model of Feitelson & Salomon a case study is used. Part of the feasibility analysis is the distribution of benefits and costs. To determine the benefits and costs, the demand for the City Coaster has to be known and a design has to be made for a specific location. Without using a case study, the demand and the benefits and costs cannot be estimated. Due to time restrictions and the fact that the City Coaster has not been designed before, only one case study will be conducted. The case study will be introduced in the next section. Figure 1-3 shows the overall research structure which will be followed in this report. The research starts with the design of the City Coaster between Rotterdam Central Station and the airport. Based on this design the demand can be estimated and the feasibility can be analyzed according to the model of Feitelson & Salomon. The results of the feasibility analysis will be used to conclude with the usefulness of the Feitelson & Salomon model.

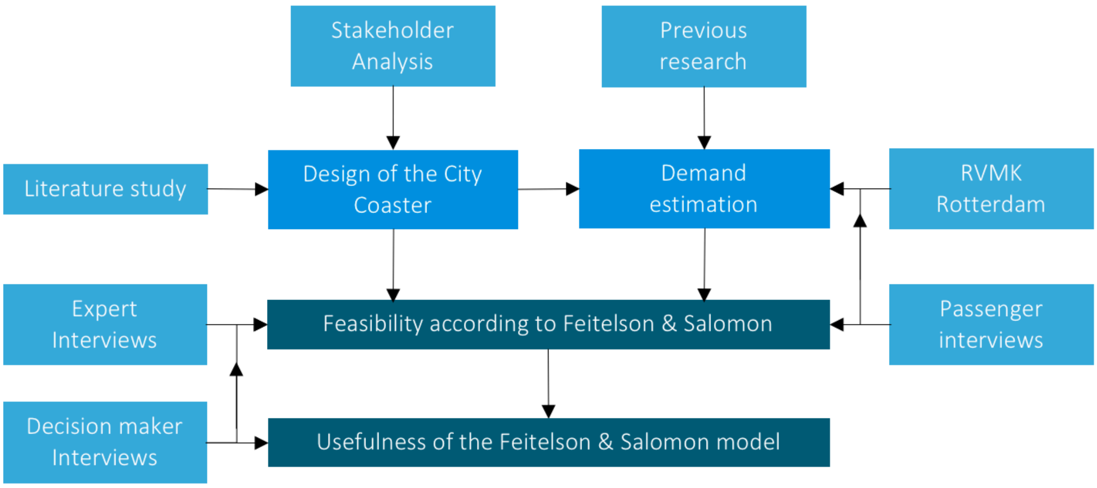


Figure 1-3: Research structure

Case study

To implement a system as the City Coaster, a location has to be chosen at which the success factors are highest and the failure factors are lowest. Therefore, the question rose which city would have a positive attitude towards a system as City Coaster? The city of Rotterdam focusses today on its architectural and innovative appearance. The City Coaster is an innovative transport system which could fit the image of the City of Rotterdam. According to Feitelson & Salomon, the political feasibility determines partially the adoption of the transport innovation. Because the City Coaster fits the image of Rotterdam, it has most potential to succeed in Rotterdam compared to other Dutch cities. Therefore, Rotterdam has been chosen as a case study.

Within Rotterdam, the accessibility of Rotterdam The Hague airport is a well-known, major issue for which the City Coaster can offer a solution. Recent research shows that the landside accessibility (other than private vehicles) of the airport has to be improved (Derksen et al., 2014). Not for nothing did the Verkeersonderneming ask for innovative ideas to make the airport better accessible by public transport. The accessibility of the airport is an important criterion for airport choice and with that also for airport competition (Reichmuth, 2010). Within the metropole Rotterdam The Hague, the airport is important for the development of the region, a good multi-modal accessibility of the airport will therefore contribute to the development of the region.

Two main public transport nodes are interesting to connect with a City Coaster to the airport: metro station Meijersplein and Rotterdam Central Station. Rotterdam Central Station is most used by current public transport users to and from the airport (66%) compared to metro station Meijersplein (26%) (Brands et al., 2015). Next to that, 55% of all travelers of the airport does not live in the Metropole region Rotterdam The Hague (Brands et al., 2015). For these travelers, a connection between the airport and a regional metro station is less interesting compared to a connection to a national (and even international) train station. As mentioned before, the Verkeersonderneming asked for innovative ideas to improve the public transport accessibility of the airport. Three participating companies tended to improve the accessibility with a connection to Meijersplein and were selected for further research. The conclusion of these three companies was that it is hard to make a business case for this connection (R. Boersma, personal communication, May 22, 2017). The passenger load to Meijersplein is currently too small for a viable business case.

Based on these three reasons, it has been chosen to only analyze the connection between Rotterdam The Hague Airport and the city center (Central Station). The connection to a national (and even international) train station is next to these three reasons, most obvious. The accessibility of Rotterdam – The Hague Airport has been discussed several times, an extension of the tram from The Hague - Delft to the airport (Derksen et al., 2014), automated vehicles from metro station Meijersplein to the airport (Verkeersonderneming, 2016) and a PRT (Personal Rapid Transit) system between Delft and the airport (van Zuylen et al., 2010-a) have been analyzed before. However, a direct connection between the airport and Central Station has not been addressed. Currently it takes 23 minutes to travel from Central Station to the airport by bus and 20 minutes with bus and light rail (9292, 2017). A shorter travel time by public transport makes the use of public transport to and from the airport more attractive. In Appendix 1 the current public transport options to and from the airport are attached.

Design of the City Coaster

For the case study, as explained in the previous section, an explorative design will be made according to the systems engineering design process as defined by Dym, Little & Orwin (2004). Following this design process in which the focus will be on defining the needs of the customer and the required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis while considering the complete problem (Ludema, 2015), will be favorable for a complex system as the City Coaster. This design process can be seen in Figure 1-4.

For this master thesis project the first 5 steps of this design process will be followed. First, the client statement or the need will be identified. After defining the need, the problem will be defined. The design objectives (1) will be clarified and based on a stakeholder analysis and interviews the user requirements (2), constraints (3) and functions (4) will be distinguished. Next, the design specifications will be established (5) and a preliminary design can be made. This design can then be tested on its feasibility (according to Feitelson & Salomon). A detailed design and design communication are not needed to analyze the feasibility and due to time restrictions, these steps will be out of scope.

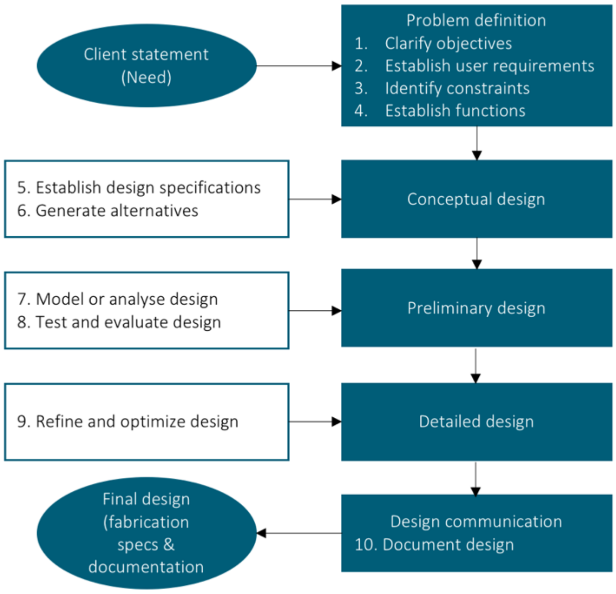


Figure 1-4: Systems Engineering Design Process. Source: Dym, Little & Orwin (2004)

The requirements, constraints and functions have to be defined to make a design. Requirements for travelers (e.g. how to handle baggage, accessibility of the City Coaster), and operators will be identified. The main input for this phase of the project are interviews with experts and stakeholders involved (including airport passengers). The stakeholders identified are the passengers, the airport, real estate developers of the area, municipality of Rotterdam, the metropole region and current public transport companies. Interviews with these stakeholders will clarify their objectives. The requirements and constraints of the airport passengers will be collected based on passenger interviews at the airport.

Additional literature study to currently available systems comparable to the City Coaster will be used as additional information. Design considerations based on comparable systems will be used to make a well-functioning design. The City Coaster can be classified as a PRT system on exclusive infrastructure. Currently, there are some comparable PRT systems in operation worldwide (e.g. Morgantown PRT, Masdar PRT, Ultra PRT and SkyCube). A system that was not implemented is for example the ARAMIS project, a PRT system studied in France for over 17 years. Not only the concepts will be discussed, also the context in which these systems operate will be analyzed. This analysis will prevent making the same mistakes as in other projects.

The output of the design phase is the layout of the stations and the track, the track suspension, the vehicle power system and the vehicle automation. The following questions can be answered based on the design phase: what is the fleet size and with that the capacity and waiting time of the system, what is the travel time and what is the energy consumption of the vehicles. These outcomes of the design are necessary to analyze the costs and benefits and with that the feasibility of the City Coaster.

Demand estimation

Because of the specific location of the case study, of which the demand estimation is complex because of the airport travelers, the only option to estimate the demand properly is by conducting a stated choice experiment. With this method, choice alternatives are presented to the interviewees. Setting up such experiment is very time consuming which makes it not suitable for this project. Therefore, it is chosen to estimate the demand based on previous research to the airport accessibility. The Rebel Group conducted an exploratory study to the public transport accessibility of the airport (Derksen et al., 2014). Following this, Goudappel Coffeng carried out a research to investigate passenger transport flows to and from the airport (Brands et al., 2015). The research of Goudappel Coffeng is based on OV-Chipcard data which makes the use of this research very reliable, it is based on observations. Because these previous researches did not involve a City Coaster, a modal shift from other transport modes can't be estimated. Therefore, a transport model will be used to estimate a modal shift. To the knowledge of the author, three transport models are available in which the airport area is included: the 'Nederlands Regionaal Model' (NRM) model, the 'Regionale Verkeers- en Milieukaart' (RVMK) of Rotterdam and the OV-Lite model for the Rotterdam Region. These models will be described below.

The NRM model is a spatial model and network model which uses discrete choice models (de Bok, 2015). In a discrete choice model, individuals have to select an option from a set of alternatives (Ortúzar & Willumsen, 2011-a). The NRM model can be used to forecast mobility developments and to estimate traffic loads on the main roads and the railroads. The model consists of four regional models: north, east, south and west (Smit & Krstic-Joksimovic, 2011). The research area of this thesis focusses on the airport of Rotterdam, it is expected that the NRM East model is not suitable to estimate a small connection in such a far-reaching model (west part of the Netherlands). Next to that, the quality of the NRM model has been discussed by, among others, TNO and TU Delft (Bates et al., 2012). Their research concludes that the model is suitable to estimate long-term forecasts and to analyze impact of transport policies. However, they also conclude that the NRM model is not explicit suitable to estimate the impact of public transport measures (Bates et al., 2012).

The RVMK model of the city of Rotterdam is also a spatial network model with discrete choice models. The model describes current and future traffic and the corresponding environmental impact for the Rotterdam region (Goudappel Coffeng, 2013-a). In this model, three transport modes are distinguished: car, public transport and bike. Within the public transport mode, no distinction is made between tram, metro, rail and bus as public transport mode, it's all public transport. The only distinction made is the travel time of the mode. This travel time depends on the speed of the mode and the number of stops. However, with this model a modal shift can be estimated based on the speed and number of stops of the transport modes (J. Rijsdijk, personal communication, March 15, 2017). The assumption that follows from this is that a traveler using public transport is not interested in the transport system itself, he/she is only interested in the speed of the connection. The type of public transport, whether it is tram, metro, train, bus or City Coaster, is not interesting for the traveler.

The OV-Lite model is a unimodal model, which only focusses on public transport. It is currently used to estimate the impact of changes in the public transport network. A modal shift to a new transport system can therefore not be estimated with this model (H. Kranenburg, personal communication, April 12, 2017).

Based on the previous description it has been chosen to use the RVMK model to estimate a modal shift towards the City Coaster. The OV-Lite model is not suitable to estimate a modal shift and the NRM model is a too far-reaching model for which it is expected that a short connection between the Central Station and the airport is hard to estimate. Because the airport has specific passengers visiting the area, interviews with airport passengers will be conducted to find out if they would use a system as the City Coaster. Questions about their current transport mode choice and their future transport mode choice if there would be a City Coaster available will be asked.

2 Comparable systems

The City Coaster has small automated vehicles operating a dedicated rail network. The City Coaster can therefore be classified as a personal rapid transit (PRT) system. A PRT system is defined as a fully automated, on-demand, and non-stop mode of transport with small vehicles (van Arem et al., 2010). PRT systems have been extensively studied in the past. However, literature study shows that only few systems have been implemented and are still in use. Why these systems failed or why other systems are a success will be described in this chapter. The systems discussed in this chapter are based on the overview of J. Edward Anderson, a PRT expert (Anderson, 2016) and the Advanced Transit Association (ATRA), an international association of transport professionals.

2.1 PRT concepts

PRT systems are studied since the 1950s. The first system having the characteristics of a PRT system was Monocab. The basis of Monocab was a monorail system with smaller and cheaper guideways. To make the guideways smaller the vehicles were designed smaller which induced reduced weight. Monocab suffered from a major disadvantage, the switch. The switch required movement of the entire guideway which made the system slow, unreliable and limited the capacity. Next to that, the hanging vehicles required a higher guideway which would have more visual impact and have higher costs (Anderson, 2016). Visual impact and high costs of the guideway were also one of the reasons why the Cabtrack system in London failed. The control system required acceleration/waiting/deceleration lanes at every junction which increased the costs and visual intrusion of the system (Lowson, 1999). Next to that, it was expected that the system could never provide sufficient capacity to carry all public transport demand in the city of London (Daniels & Warnes, 1980). Also, the lack of political support by the new Minister of Environment who stopped the research program contributed to the failure of this system (Anderson, 2016). Safety regulations caused the CVS system in Japan to fail. The rail safety regulations required minimum headway times that could not be fulfilled by the system (Anderson, 2016). A unique system compared to the previous mentioned systems was Aramis because the vehicles were driving in platoons. This had to be achieved by ultrasonic and optical sensing. It would allow a higher throughput of vehicles in busy areas and vehicles could merge/separate as they approached their destination. After years of research it was still technically not feasible which made the company behind it decide to shut down the project (Latour, 1996). The Cabintaxi project in Germany was technically feasible and passed all safety tests. Therefore, a large scale Cabinentaxi implementation in the city of Hamburg was planned (Bendixon, 1972). Nevertheless, due to budgetary constraints, the Hamburg and Cabintaxi projects were halted in 1979. (Carnegie & Hoffman, 2007). A system that dealt with all previous mentioned issues was Taxi 2000. The system consisted of small automated vehicles on a light track. After a successful design, it was investigated to implement Taxi 2000 in the Chicago area. For the development of the system a public private partnership was founded with Raytheon Corporation. They changed the design of the Taxi 2000 into a heavier system which made the project more expensive. In the end, the program was cancelled mainly for economic reasons (Carnegie & Hoffman, 2007).

Figure 2-1: Left: CVS test facility Tokyo, center: Aramis test facility, right: Cabintaxi test facility (reprinted from Khammas 2017)

2.2 Real life applications

This subchapter will introduce four PRT systems that were implemented in real life. The first operated PRT system is the system in Morgantown. It is a five-station system which connects the three West Virginia university campuses with each other, and with the city center. The system consists of a fleet of 71 electronically powered by the track, rubber-tired vehicles that operate with a speed of 50 km/h on a 14-kilometre dedicated track and have a capacity up to 21 passengers. The guideway comprised most the costs of the Morgantown PRT system (Raney & Young, 2004). This can be explained by the fact that the vehicles are powered by the track, communicate via the track and the track is equipped with heating pipes to melt snow. The success of the Morgantown PRT system can be explained by the fact that it was funded as a demonstration project and was used as a show piece in the presidential elections by president Nixon. However, the pressure from the administration to complete the project before the next election and the uncertainty of the new technology resulted in a system that passed its budget four times and cost 130 million dollars.

Since 2010, a PRT system is operating in Masdar City. It connects a car park with the Masdar Institute of Science and Technology. The system has a length of 1.5 kilometers and consists of a fleet of ten driverless vehicles offering space up to 6 passengers and which are entirely powered by batteries that are charged at the stations. Passengers board and unboard at angled stations, which makes it possible to entry and exit independently of other vehicles. The vehicles have an average speed of 4 m/s. The vehicles operate according to virtual routes which are set by magnets embedded in the corridor (Mueller & Sgouridis, 2011). On-board sensors detect obstacles in the vehicle path. The system operates only on demand, if no demand is available, the ten vehicles will be stored at the ten stations which leads to minimal waiting times (de Graaf, 2011). The PRT system in Masdar City was initially designed as an alternative for cars in the entire city. Economic considerations have resulted in the decision to not extend the system through the whole city (PRT Consulting, 2010).

One year later, the Ultra PRT system was opened for public which connects the London Heathrow airport terminal 5 with its car park. The system consists of two two-angled stations at the parking facility connected via a 3.8-kilometre dual-guideway with one four-angled station at the terminal. It has 21 rubber-tired electric vehicles which are charged at the stations and in the buffer zone (Bly, 2011-a). The average speed of the vehicles is 40 km/h and they are guided on the guideway using lasers to verify the vehicle location continuously. The vehicles are protected by a fixed block system which are set by inductive loops (Ultra Global PRT, 2011). The costs of the current PRT system are estimated at £30 million. The extension of the system to other terminals has been postponed. The amount of capital the airport could deploy was limited and other projects at the airport had greater priority (Lawson, 2014).

The last PRT system that will be mentioned here is the SkyCube PRT system which has been designed by Vectus and is running in Suncheon, South Korea since 2014. It provides transport to the protected wetland area of Suncheon Bay for the three million annual visitors to the reserve. The SkyCube is a PRT system running on a dedicated rail track and has only two stations with four in-line berths each and a 4.6 km guideway. The fleet consists of 40 electric vehicles powered by a power collecting system installed along that guideway. The guideway has no moving parts, switching is done on-board, comparable to the Morgantown PRT system. The vehicles have an average speed of 40 km/h and are separated using dynamic moving blocks (Choi, 2015; Pemberton, 2012).

Figure 2-2: Upper left: Masdar PRT, upper right, London Heathrow, lower left (Suncheon PRT) lower right: Morgantown PRT (reprinted from Khammas, 2017; PRT Consulting, 2015; ARUP, 2017)

2.3 Design considerations for the City Coaster

Based on the systems described in section 2.1 and 2.2, design considerations for the City Coaster can be established. These considerations are used for the design of the City Coaster. According to the not implemented systems the City Coaster can be a success if

- it has a simple and light guideway with no moving parts
- it is a technical feasible system
- it complies with safety regulations
- it has political support

The Morgantown system showed that with subsidy from the government it can be a success. The system has been developed under political pressure which was one of the reasons the system was not built within budget. However, compared to the other abovementioned systems, it is a public transport mode in the city of Morgantown which is still in use. The other three, recently implemented systems do not fulfil this task. They are used as a direct connection between specific origin and destination. The Masdar

PRT system connects a parking facility with the Masdar Institute of Science and Technology, the Ultra PRT system connects a parking facility with an airport terminal and the SkyCube system provides transportation to a tourist hotspot. Another factor that is worth mentioning is ownership. Masdar PRT is owned by a state-owned company of Abu Dhabi, which is led by the crown prince of Abu Dhabi. The PRT system at London Heathrow is owned by the airport, which is in private possession and the SkyCube system is owned by steel producing company Posco. These systems did not require public investment which made it easier to implement. These four applications show that the system is a success if the system is subsidized by the government or is privately owned and thus does not require public investment.

The abovementioned considerations will be used in the design of the City Coaster. The not implemented systems showed that the guideway costs determine the economic feasibility of the system. Therefore, the guideway of the City Coaster has to be as cheap as possible. On the other hand, safety regulations should be investigated as well to prevent that the system can't be operated because it does not fulfil the requirements of the safety regulations. The design considerations will be used in Chapter 4 as requirements for the City Coaster.

3 Stakeholder analysis and requirements

Part of the design cycle defined by Dym, Little & Orwin (2004) is to clarify objectives and establish user requirements. These will be identified based on a stakeholder analysis. The stakeholders are selected based on the snowball effect, two main stakeholders were identified first after which other stakeholders could be identified. For the design of the City Coaster the following stakeholders have been identified: the airport, the Metropole region Rotterdam The Hague, passengers, real estate developer of the area, the municipality of Rotterdam and current public transport companies. To understand the objectives and requirements set by the stakeholders, interviews with the stakeholders were conducted.

Next to the requirements of the stakeholders, technical requirements for automated people mover systems set by the American Society of Civil Engineers (ASCE) will be used. These standards were also used for the design of the PRT system in Suncheon. According to the standards of the ASCE (ASCE, 2014) the system must have automated train protection (ATP) functions in which train presence is detected and separation is assured. In case of an elevated guideway, the passengers have to be able to evacuate the vehicle in case of an emergency. Lastly, the construction of the track must be protected against a vehicle (bus, truck, etc.) hitting the posts of an elevated guideway (ASCE, 2014). If the posts are damaged, the City Coaster cannot be operated anymore.

Rotterdam The Hague Airport

Objective: developing the airport by extending the network of destinations to satisfy the increasing demand of passengers.

Requirements: reliable and predictable transport, cope with high peak demand of approximately 100 public transport passengers if two foreign flights arrive at the same time, operable before 5.00 a.m. and after 12.00 a.m.

The airport contributes to the economic development of the region by connecting economic centers in Europe with the metropole region and by providing leisure trips to and from the region. To facilitate the growth of the airport, an improved public transport accessibility is necessary. A modal shift to public transport caused by a better public transport connection ensures that the current parking capacity is sufficient to facilitate the future growth. It has to be reliable that in case of a disruption caused by a malfunctioning vehicle, the system must still be operable. In this case, the failing vehicle has to be brought to a maintenance site so the operation of the system is not hampered by this vehicle.

Metropole region Rotterdam The Hague

Objective: to become a leading European region by focusing on improving (international) accessibility of the region, economic renewal, transition to leading sustainability and attractiveness of the region (MRDH, 2017).

Requirements: direct connectivity to multiple regional destinations, it has to be better than the current bus system (regarding travel and waiting time), it has to be able to deal with the peak demand at the airport.

The metropole region is a collaboration of 23 municipalities around Rotterdam and The Hague. They combined their forces to make the region more accessible and enhance the economic value of the region. The metropole region is therefore, among others, responsible for transportation in the region and they grant concessions to public transport companies.

Passengers of the City Coaster

Objective: travel safe, fast and reliable to and from the airport.

Requirements: short in vehicle time, high frequency, no or short waiting times, reliable, seat availability, space for luggage, short access and egress distances, accessible by disabled people, social safety inside the vehicles and at stations, compatible ticketing system with OV-Chipcard, clear travel information.

The City Coaster will transport two groups of people: airport passengers and employees of the airport and companies. The passengers will use the system and therefore benefit the most of a better connection between the train station and the airport. The objective and requirements are based on the interviews with airport passengers (which will be elaborated on in Chapter 5.5) and inquiry by the travelers' advisory body METROCOV which is representing travelers in the metropole region.

Schiphol Real Estate

Objective: develop preferred locations for companies, their employees and their guests and to maintain and improve the occupancy rate of their real estate (Schiphol Real Estate, 2017).

Requirements: good multimodal connectivity of the area, attractive to business people, viable business case.

Schiphol Real Estate is engaged in developing, investing in, managing and maintenance of commercial real estate at the business parks at Amsterdam Airport Schiphol, Rotterdam The Hague Airport, Eindhoven Airport and Milan Malpensa Airport.

Municipality of Rotterdam

Objective: to be attractive for inhabitants, businesses and visitors by having a strong economy and an attractive city (Gemeente Rotterdam, 2017).

Requirements: technically feasible, economically feasible, technically safe, socially safe, impact on the surrounding space has to be minimalized.

Rotterdam The Hague airport is important for the city of Rotterdam, it contributes to the international profile the city would like to appear. Therefore, a good public transport connection to the airport is important. The current bus line is used sufficient and the travel time is comparable to other connections between airports and city centers. Nevertheless, the use of public transport to and from the airport is too low. For the connection between the airport and Rotterdam Central Station, the municipality expects that a connection near Park 16Hoven and the allotments (in Dutch: volkstuinen) should not count on public (and with that political) support. The owners of the allotments had to deal with spatial changes in the past, it is not expected that a City Coaster will be accepted by the owners. Next to that, the proposed track passes recently new developed residential villas.

Public transport company: RET

Objective: providing perfectly organized and executed public transport with the highest quality for the travelers (RET, 2017).

Requirements: viable business case, technically feasible, evacuation possibilities in case of an emergency, maintainable, sustainable, able to satisfy the demand.

The RET is the main public transport provider in the city of Rotterdam. The company offers bus, tram and metro services and is currently responsible for the bus connection to the airport. It is expected that because of the low demand to and from the airport, a conventional bus system is cheaper to operate instead of investing in a new system.

Rail infrastructure manager ProRail

Requirements: a system near the railroads has to be inspectable and maintainable without affecting the other rail operations, a system over the current rail tracks must have a minimal height distance from 7500 mm from the top of the track and a system along the rail roads must have a horizontal distance of 3.75 m from the center of the track.

Because the connection from Central Station to the airport runs parallel to, and crosses the railway track, the City Coaster must at least fulfil the requirements set by ProRail to build near or above railway tracks. If the City Coaster does not fulfil these requirements, ProRail will not accept a system as the City Coaster near its own rail tracks. These requirements are arranged in "Ontwerpvoorschrift Kunstwerken – deel 2 – Bouwwerken over en naast het spoor" (ProRail 2015).

Remark regarding this stakeholder analysis

Based on the interviews, objectives and requirements have been drawn up. It should be mentioned here that during every interview the stakeholders were surprised about the connection chosen. METROCOV, RET and the municipality of Rotterdam even advised to change the City Coaster to Meijersplein instead of Rotterdam Central Station. However, as mentioned in the introduction, because of the current use of Bus 33, the national demand of the airport and the non-viable business cases to Meijersplein, the connection to Central Station has been chosen a priori, the connection to Central Station will be analyzed in this report. If it turns out that the City Coaster is feasible according to the model of Feitelson & Salomon (2004), further research can be conducted to a City Coaster to Meijersplein. It will be reflected on this location in Chapter 8.

4 Design of the City Coaster

Based on the analysis to previous PRT systems in Chapter 2 and the requirements of the stakeholders Chapter 3 a design of the City Coaster can be made for this explorative research. The design of the City Coaster will consist of the following components: the track design, the track and station layout, the travel time, the fleet size, the waiting time and the capacity, the power system and the energy consumption. This chapter is mainly based on literature study.

4.1 Track design

For the track design a distinction has been made between the track suspension, safety and the layout and the buffer zone of the vehicles.

4.1.1 Track suspension

Two types of vehicle suspension are available for the City Coaster: overriding suspension and underhung suspension. Underhung suspended systems are mainly being seen in monorail or metro systems (e.g. Wuppertaler Schwebebahn). The advantages of an underhung suspension are that the track cannot be covered with snow or ice and the torsional load in curves is lower compared to an overriding suspension (Anderson, 2016). Disadvantages of an underhung suspension for PRT systems are identified by Irving et al. (1978). The bottom of the track must be higher than the bottom of an overriding suspension which implies that the columns under the track have to be higher. The columns are located on the side, with a cantilevered support of the track. This causes higher investment costs and moreover, more aesthetic impact, especially if the system can be installed at street level. Because the advantages of an underhung suspension are minor compared to the disadvantages (investment costs and aesthetic impact) an overriding suspension has been chosen for the City Coaster. It has to be noted here that this overriding suspension has to be cleared from snow and ice in winter conditions. According to experts of VEKOMA and Huisman, a well-known Dutch Rollercoaster design company and a manufacturing company of heavy construction equipment respectively, this can be solved by equipping one vehicle in the system with de-icing equipment (J. Philippen, personal communication, May 11, 2017).

4.1.2 Track safety

As mentioned in Chapter 3, the system needs to have evacuation possibilities in case of an emergency. Compared to conventional rail systems the City Coaster is different because of the light design. If a conventional rail system has an elevated track, mainly U-profiles are used as construction. The advantage of this profile is that a walkway can be easily positioned on top of the construction. The design of the City Coaster is compared to that different because there is no space available on the construction for a walkway. Installing evacuation walkways along the track is not an option because this has a major impact on the 'light' design of the City Coaster and will cause more visual intrusion. Therefore, other solutions have to be conceived. For comparison, there are monorail systems and automated people movers which have no evacuation walkways either. Nevertheless, the City Coaster needs to be safe for the passengers. Next to evacuation walkways along the track other evacuation possibilities are possible. Monorail systems have evacuation possibilities by using so called escape slides. Next to that, rear to front, front to rear or side to side evacuation is possible by using other (empty) vehicles. These options can be used in critical situations. In case of a failing vehicle evacuation is not necessary, other vehicles have to push the failing vehicle to a station. However, because it is a new system of which no directive exists, the final decision regarding the design of the evacuation possibilities must be taken by the responsible authority in consultation with emergency agencies.

4.1.3 Track layout

In this research, the connection between Rotterdam Central Station and the airport will be explored. According to the requirements, the stations must have a short as possible walking distance to and from the other transport modes and to the terminal. As can be seen in Figure 4-1, a City Coaster station at the southern part of Central Station is therefore favorable. From this location the train, metro, tram and bus can be reached with the shortest walking distance. Between Central Station and the bus station there is space available which is currently used as recreation area. However, according to the land use plan of this area, it can be used as office space in the future. Another option is a City Coaster station above the current bus station, other options at this location are not possible due to lack of space. A stop at the north side of Central Station is not favorable because the walking distance to the metro would increase and passengers have to walk through the station which is secured with OV-Chipcard gates. This would require an additional check-inn and check-out for City Coaster passengers arriving from the southern part. At the airport, the stop can be built in the terminal or close to it. There are no specific constraints that have to be considered. A stop within the terminal would be preferred by the passengers.

Figure 4-1: Current situation at Rotterdam Central Station

A short as possible track saves costs and reduces the travel time. Figure 4-2 shows a top view on the City Coaster track which can be seen in red. This track fulfils the requirements set by ProRail (horizontal distance of 3.75m and vertical distance of 7.5m) and is 4.7 kilometers long (single). The distances between the City Coaster track and the ProRail tracks are checked in Railmaps, an online tool of ProRail in which track information is stored.

The track of Figure 4-2 crosses the allotments and the residential villas as mentioned by the municipality in the stakeholder analysis. Unfortunately, there is no other track possible due to the residential area Park16Hoven. If the residents of the allotments and the villas are against the City Coaster, a tunnel could offer an alternative. However, this will induce more investment costs. This will be further discussed in Chapter 8. In Appendix 2, a height profile of the track is attached. This profile is based on the 'Actueel Hoogtebestand Nederland' (AHN2) in which detailed and precise height measurements with on average eight measurements per square meter are stored (AHN, 2017).

Figure 4-2: City Coaster top view map

4.1.4 Buffer zone

To store the vehicles which are not in use and to carry out maintenance on the vehicles, the system must have a buffer zone and a maintenance site. For the buffer zone, two options are available. The vehicles can be stored at the berths at the stations or a dedicated buffer area has to be designed. This buffer area requires two additional switches in the track which increases the investments costs. Next to that, the system has only two stations, one at the airport and one at Central Station. If the system would have more stops, a buffer zone and off-line stations would be required to not affect the capacity (Anderson, 2016). Therefore, the vehicles will be stored at the stations. A maintenance site is required in case a vehicle fails. In case of a failing vehicle on the track, the system can't be operated anymore. This vehicle must be brought to a site at which it has no influence on the operations of the system. A potential lay out of the station and the maintenance site at the airport can be seen in Figure 4-3.

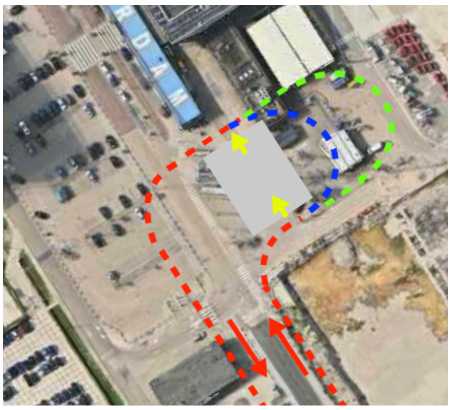


Figure 4-3: Potential lay out at the airport, in red the City Coaster track, blue the maintenance track and green the buffer zone. In grey, the station can be seen. On the one side egress and on the other side access platforms.

4.2 Travel time

The travel time of the City Coaster plays a role in the mode choice for the City Coaster. Therefore, the travel time has to be as short as possible. As mentioned in Chapter 2, current PRT systems have a speed between 25 and 50 km/h. Especially the systems with a dedicated rail have a higher speed. Next to that, current rollercoasters can have a speed up to 240 km/h (Chang, 2016) caused by gravity. However, such high speeds are from a comfort point of view not desirable. A speed of 50 km/h, comparable to the speed of the Morgantown PRT system is therefore chosen for the City Coaster.

For the acceleration and deceleration of the vehicles a comparison with private cars and trains has been made to benchmark the rates of the different transport modes (Table 4-1). The acceleration and deceleration rates of private cars are based on the Dutch manual for traffic lights (Wilson, 2014), the rates for a train are not recorded in literature and are therefore based on statements on the internet.

Table 4-1: Acceleration and Deceleration rates for private vehicles and trains

	Acceleration	Deceleration
Car	4-5 m/s^2	2.8 m/s^2
Train	0.5 m/s^2	0.8 m/s^2

According to the requirements set by the American Society of Civil Engineers (ASCE, 2014) the maximum acceleration and deceleration must be lower than 2.45 m/s^2. Because it is expected that the City Coaster is able to accelerate and decelerate faster than a train, the acceleration and deceleration rate must be between 0.5 and 2.45 and 0.8 and 2.45 respectively. Therefore, an acceleration and a deceleration of 1.5 m/s^2 has been chosen for the City Coaster.

The total distance of the track between Central Station and the airport is 4.7 kilometers long. Taken into account a speed of 50 km/h and an acceleration and deceleration rate of 1.5 m/s^2 a travel time can be estimated of 5.8 minutes (Appendix 3).

4.3 Number of vehicles, waiting time and capacity

The number of vehicles are calculated based on a frequency based calculation in Microsoft Office Excel. According to the requirements, the City Coaster has to be able to cope with the high peak demand caused by airport passengers. There must be enough vehicles available to cope with a peak demand of approximately 100 passengers if two airplanes arrive at the same time. This occurs when two airplanes arrive with mostly foreign travelers. Observations at the airport showed that the peak of passengers leaving the airport will occur ten minutes after arrival of the airplane for business flights and 20 minutes after arrival of leisure flights (see Figure 4-4). This can be explained by the fact that leisure passengers have more checked-in baggage compared to the business passengers. The leisure passengers have to wait for their baggage before they can leave the airport.

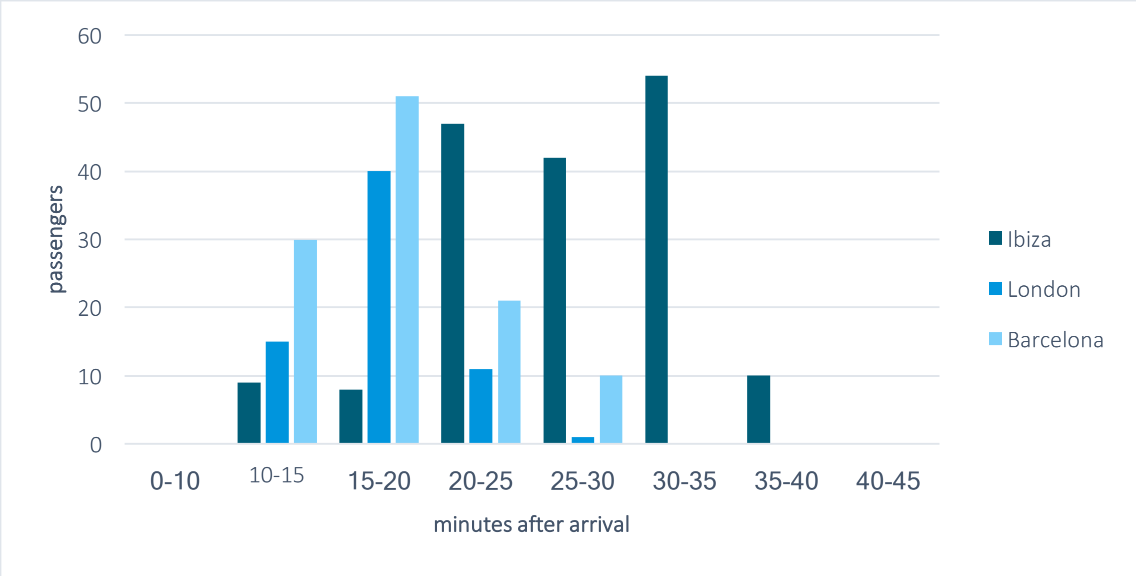


Figure 4-4: Passenger load leaving the airport after arrival of the airplane. Source: own observations

In this case, approximately 100 passengers use public transport within 20 minutes. The distribution of passengers is based on Figure 4-4 of which the average of the Barcelona and London flight has been used. The five-minute distribution from the figure has been transformed in proportion to a distribution of 30 seconds. For example. If 10 people arrived in 5 minutes, then 1 person arrives per 30 seconds. The 30 second distribution can be found in Appendix 4. As mentioned in section 4.2, the travel time has been estimated to 6 minutes. With an access and egress time of 45 seconds each at both stations the round time of a vehicle can be estimated to 15 minutes. The distribution from Figure 4-4 has been analyzed in Excel in which the vehicle capacity and number of vehicles (and with that the frequency and headway time) are varied. Based on the vehicle capacity and the number of vehicles the cumulative waiting time, maximum waiting time and average waiting time has been estimated. The results can be seen in Table 4-2. The corresponding figures can be found in Appendix 5.

The requirement of the airport was that a new system has to perform better than the current bus system. Therefore, the same analysis has been conducted for the current bus with a frequency of 6 busses per hour. The cumulative waiting time varies between 450 to 500 minutes, dependent on the scenario in which the bus arrives. If the bus arrives at minute 0 and at minute 1 the passengers, they have to wait longer than if a bus arrives at minute 5 and at minute 1 the passengers. If the City Coaster has to be better than the current bus system, the cumulative waiting time must be lower than 450 seconds and the maximum waiting time must be lower than 10 minutes (red numbers in Table 4-2). A vehicle fleet of 30 vehicles is because of economic reasons not desirable. On the other hand, the vehicle has to be as light as possible, the more people are in the vehicle, the heavier the vehicle will be. Next to that, in case there is no peak demand (e.g. from Central Station to the airport), passengers should not have to wait for other passengers because the vehicle has such high capacity. Therefore, from an airport passenger point of view it is required to have 15 vehicles with a vehicle capacity of 6 passengers or 10 or 15 vehicles with a capacity of 8 passengers.

Table 4-2: Headway time and corresponding frequency and fleet size, cumulative waiting time and maximum waiting time

Vehicle capacity [pax]	Number of vehicles [-]	Frequency [h^{-1}]	Headway [min]	Cumulative waiting time [min]	Maximum waiting time [min]	Average waiting time [min]
2	30	120	0.5	483	9	4.8
2	15	60	1	1797	33.5	18
4	30	120	0.5	38	1.5	0.38
4	15	60	1	500	9.5	5
6	15	60	1	165	4	1.7
6	10	40	1.5	545	10	5.5
8	15	60	1	47	1.5	0.5
8	10	40	1.5	247	5.5	2.5
8	7.5	30	2	552	10.5	5.5
10	15	60	1	25	0.5	0.3
10	10	40	1.5	129	3.5	1.3
10	7.5	30	2	300	6.5	3
10	6	24	2.5	575	11	5.8
12	10	40	1.5	77	2	0.8
12	7.5	30	2	189	5	1.9
12	6	24	2.5	370	7.5	3.7
12	5	20	3	604	11.5	6

Next to the airport passengers, the City Coaster system is also used by employees of the area. The REBEL Group (Derksen et al., 2014) estimated a total of 2.500 jobs at the airport area. Assuming a public transport modal split of 10 % and a normal distribution (Appendix 6) in the morning peak between 8.00 A.M. and 9 A.M. the cumulative waiting time with 15 vehicles and a capacity of 8 passengers would be 194 minutes, the average waiting time 0.8 minutes and maximum waiting time 2 minutes. With 10 vehicles and a capacity of 8 passengers, this would increase to 1558 minutes, 6.5 minutes and 14.5 minutes respectively. 10 vehicles with a capacity of 6 passengers will even be worse. Knowing this and looking ahead to chapter 5, a vehicle fleet of 15 minutes with a capacity of 8 passengers has been chosen. With 15 vehicles, a frequency of 60 vehicles per hour can be achieved. This would induce a capacity of 480 passengers/hour per direction.

4.4 Power system

The City Coaster has electric vehicles on a rollercoaster track. These electric vehicles can be powered by three systems; an overhead catenary, a power system in the track or batteries in the vehicles. The overhead catenary will not be discussed here, the aesthetic impact of this system makes it unusable for the City Coaster. A power system in the track can be established in two ways: contact and contactless systems. Contact systems use an embedded third rail, contactless systems use an induction coil in the track (Agirre & Abad, 2016). Third rail systems feed the vehicles via a flat shoe that is connected to the third rail continuously which is mostly used in metro applications. Induction coil systems transfer the energy to the vehicle by an inductive magnetic field. As the vehicle runs over the magnetic field, an onboard receptor converts it into electrical energy. Another worth mentioning contactless system is a magnetic levitation system in which the vehicles move because of magnetic forces between the vehicle and the track. An advantage of this system is that the power equipment is located wayside which makes the vehicle lighter (Agirre & Abad, 2016). However, power systems in the track need specialized infrastructure and vehicle equipment, which leads to significantly more technical problems than on-board energy storage systems (e.g. batteries), especially for light weight vehicles. The reliability of power systems in the track is an issue and they are sensible for water, snow and ice conditions (Agirre & Abad, 2016). Therefore, it is chosen to use battery powered vehicles instead of a power system in the track.

By placing batteries inside the vehicles, no power system along the track is required to power the vehicles. Battery prices reduced the last six years by almost 80% because of the continued electric vehicle sales growth. Currently battery prices decreased to 230$ (205€) per kilo Watt hour (McKinsey, 2017). The disadvantage of batteries inside the vehicles is that the vehicle weight increases. According to Young et al. (2013) electric vehicles on the market mostly use Lithium-ion (Li-ion) or nickel-metal hydride (NiMH) batteries. Li-ion batteries have a specific energy of 0.125 kWh/kg (e.g. 8 kg/kWh) which is higher than NiMH batteries (0.07 kWh/kg, 14.3 kg/kWh) (Manzetti & Mariasiu, 2015) which makes the use of Li-ion batteries more interesting for an application as the City Coaster. One disadvantage is the durability of batteries, it is well known that the capacity of batteries decreases over time. Steinbuch (2017) estimated the battery degradation per kilometers driven of an electric vehicle, the Tesla model S. After 240,000 km, the energy capacity of the battery has been estimated to be 90%. If the degradation is linear, every 24,000 km the battery capacity decreases with 1%. If the batteries are replaced every 15 years, 87 single trips per day can be made with every vehicle which is more than sufficient.

4.5 Energy consumption

The energy consumption of electric vehicles can be calculated based on the air resistance, rolling resistance, gradient of the track, and the acceleration force (Young et al., 2013). The total resistance forces have to be equal to the drive power of the vehicle. The Resistance forces can be calculated as (Young et al., 2013):

$$F_{tot} = F_{air} + F_{roll} + F_{gradient} + F_{acceleration}$$
$$= \frac{1}{2} * \rho_L * c_w * A * (v + v_w)^2 + m * g * f * \cos(\alpha) + m * g * \sin(\alpha) + m * a$$

The calculation for the track between the airport and central station can be found in Appendix 7. For this calculation, assumptions were needed. These assumptions are based on comparable calculations (Oeser, 2012; Young et al., 2013; Meywerk, 2015). It is assumed that the air density is equal to 1.2 kg/m^3, the aerodynamic drag coefficient c_w equal to 0.8, the vehicle frontal area A is equal to 2.0 m^2 and the coefficient of rolling resistance f is equal to 0.01. The average wind speed at Rotterdam The Hague airport is according to Windfinder 55 km/h (Windfinder, 2017). It is assumed that this wind moves in the opposite direction as the vehicle (worst case scenario). Alpha depends on the gradient which follows from the track lay-out. The vehicle weight has been assumed to be 2250 kg. This assumption is based on the weight of the Ultra PRT Pods at London Heathrow airport (850 kg empty weight for four passengers) and a passenger weight for eight passengers of 100 kg including luggage (800 kg). Based on the abovementioned equation, 1.41 kWh energy would be required for a single ride.

5 Demand estimation

The City Coaster will offer a faster connection from Rotterdam Central Station to Rotterdam The Hague Airport. Two groups of people visiting the airport area can be classified: airport passengers and employees of the companies in the airport region (including airport employees). An estimation of the demand of these two groups of people will follow in this chapter. Multiple sources are available to make an estimation of the demand, these sources will be described first. With these sources, a current and future demand can be estimated.

5.1 Methods to estimate the demand

The demand to and from the airport is dependent on airport passengers. Therefore, airport data will be analyzed first. Yearly data available from the airport and OAG (Air Travel Intelligence) data from earlier research from Brands et al. (2015) between August 2014 and July 2015, will be used.

The second source that will be analyzed are interviews with airport passengers conducted at the airport by the airport itself. Based on these interviews the current modal split of airport passengers has been estimated. The interviews were conducted from July 2014 until June 2015. In total 3412 respondents participated in the interviews.

Second, OV-Chipcard data of bus line 33 has been used. In the current situation, the only public transport mode to and from the airport is bus 33. If visitors to the area are travelling by public transport, they have to take bus 33. Therefore, the OV-Chipcard data of this bus line will be analyzed to find out where the users of the bus are coming from and are going to. OV-Chipcard data of the month May 2015 is available for this research.

Because these before mentioned sources only focus on the current demand to and from the airport, the transport model of the City of Rotterdam will be used to analyze a modal shift to the City Coaster. The current model split, based on the airports modal split, OV-Chipcard data and data about employment in the region will be used to validate the model split in the original model. Because the airport has specific passengers visiting the area, interviews with airport passengers will be conducted to find out if they would use a system as the City Coaster. Questions about their current transport mode choice and their future transport mode choice if there would be a City Coaster available were asked. A comparable interview was suggested for the companies around the airport. Unfortunately, the employees were not interested and the response was low. Further research should pay attention to the employees of the area.

Lastly, the demand growth will be analyzed based on growth scenarios of the airport and office space around the airport.

5.2 Airport data

In 2015, 1.7 million passengers travelled via Rotterdam – The Hague Airport of which 1.6 million passengers were passengers of charter and line schedule flights (see Appendix 8). These flights are for this research most relevant compared to passengers of the other flights (e.g. ad hoc and transit passengers). The airport has a seasonal demand with a maximum in May and a minimum in November, see Figure 5-1. On average, 47 flights arrive and depart per day with on average 94 passengers per flight to and from the airport which induces an average of 4466 passengers per day in 2015 (RTHA, 2015). However, due to the seasonal demand the number of passengers per day fluctuates, in May 6100 passengers arrived and departed. In November, this decreased to 2800 passengers.

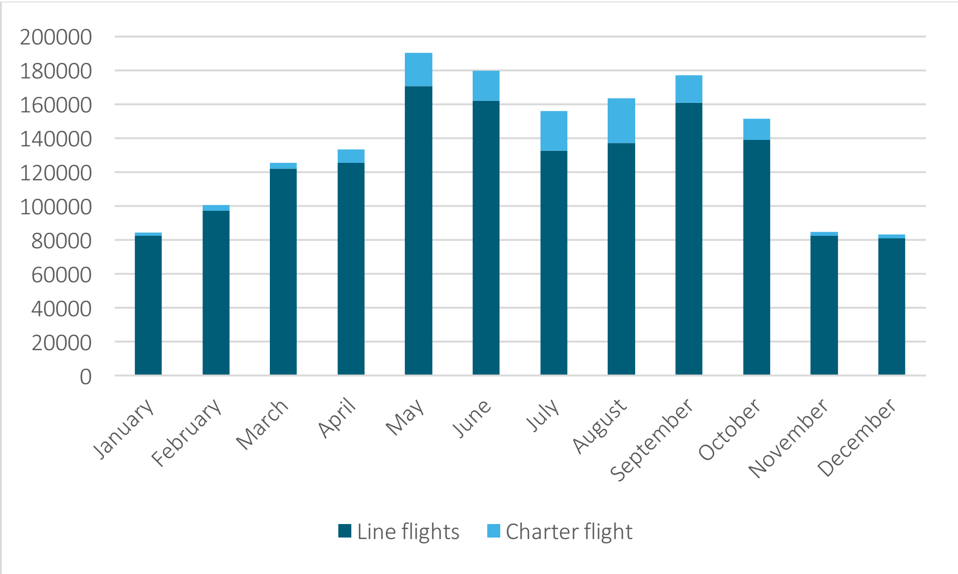


Figure 5-1: Airport passengers in 2015. Source: RTHA, 2015

On Fridays most seats depart, on Saturdays the least seats depart. This can be explained because most leisure flights depart on Friday and least business flights depart on Saturday. It is assumed that the number of arriving seats is equal to the number of departing seats because most airplanes arrive at an airport and depart to another destination from the same airport. Zooming in on a day, the flight pattern of the airport shows departure and arrival peaks. In the early morning, afternoon and early evening a departure wave occurs. Flights arrive at the end of the morning, late in the afternoon and late in the evening (Brands et al., 2015).

5.3 Current public transport demand to and from the airport

The current public transport demand will be estimated based on the airport's interviews with airport passengers and by analyzing OV-Chipcard data.

5.3.1 Interviews with airport passengers

From July 2014 until June 2015 the airport conducted passenger interviews at the airport, only departing passengers were interviewed. In total 3412 respondents participated in the interviews. It is assumed that every departing passenger also returned to Rotterdam – The Hague Airport. Of these departing passengers, only 15% was on their return flight, which indicates that 85% started their trip from the airport (Brands et al., 2015). The top 10 of origins of the passengers can be seen in Table 5-1. Of the outgoing passengers, only 42% of the passengers originates from within the region Rotterdam – The Hague. This confirms the national demand as mentioned in Chapter 1.3. On the other hand, of the return passengers 64% had their destination within the region Rotterdam – The Hague.

Table 5-1: Origins of outgoing passengers and return passengers. Source: Brands et al. (2015)

Outgoing passengers		Return passengers	
Rotterdam	10%	Rotterdam	29%
The Hague	9%	The Hague	19%
Amsterdam	2.5%	Delft	6%
Delft	2%	Amsterdam	5%
Breda	2%	Breda	3%
Zoetermeer	2%	Utrecht	1.5%
Utrecht	1.5%	Haarlem	1%
Dordrecht	1.5%	Leiden	1%
Hellevoetsluis	1.5%	Voorburg	1%
Spijkenisse	1%	Rijswijk	1%

The modal split of the interviewees can be seen in Figure 5-2. Only 12% of the interviewees travelled by public transport to the airport. A high value for car use of 77% can be explained by the good car accessibility of the airport. The airport is located near highway A13 from The Hague and A20/A16 from Gouda and Dordrecht respectively.

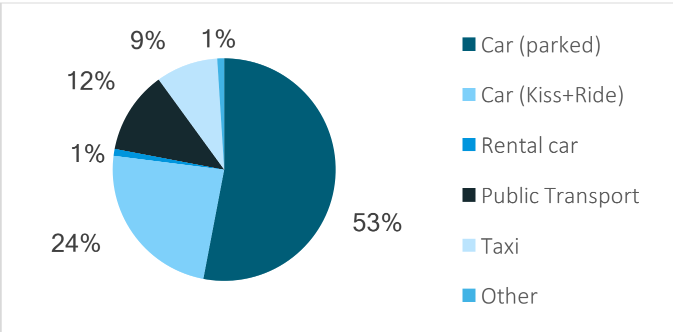


Figure 5-2: Modal split of airport passengers based on interviews. Source: Brands et al. (2015)

5.3.2 OV-Chipcard data

People travelling to the airport by public transport have to take bus 33, there is no other public transport option available. Therefore, OV-Chipcard data of bus 33 from May 2015 has been analyzed. The data has been collected for weekdays, Saturdays and Sundays. In total, May 2015 had 21 weekdays, 5 Saturdays and 5 Sundays. The data is provided for every check-in and check-out combination in bus 33. Based on this data, origin-destination matrices have been made for bus 33 in May 2015. These are attached in Appendix 9. Table 5-2 shows concisely the results of the OV-Chipcard data analysis. It can be seen that 71.6% of all trips made with bus 33 were not airport related. This can be explained by the fact that bus 33 is the direct public transport connection between the city center and Overschie. Airport related trips are accountable for 21.6% of all trips. 6.8% of all check-ins where not coupled to check-outs, it is not known where the people left bus 33, this caused, unfortunately, errors in the data.

Table 5-2: OV-Chipcard data of Bus 33 in May 2015 (two-way)

	Weekday		Saturday		Sunday		Month	
Connection	Total	%	Total	%	Total	%	Total	%
Airport - Central Station	9970	13,4	1383	11,2	2365	19,9	**13718**	**14,0**
Airport - Meijersplein	4691	6,3	426	3,4	620	5,2	**5737**	**5,8**
Airport – Elsewhere	1275	1,7	163	1,3	280	2,4	**1718**	**1,8**
Other - Other	53573	72,3	9511	76,9	7411	62,3	**70495**	**71,6**
Unknown	4631	6,2	881	7,1	1217	10,2	**6729**	**6,8**
Total	74140		12364		11893			

For this research, the connections between the airport and Central Station and Meijersplein are most interesting. On average, 628 trips ((13718+5737)/31) between the airport and Meijersplein or Rotterdam Central Station were made per day in May 2015. Table 5-3 shows the data specific for the connections to and from the airport stop. As can be seen from this table, 65% of the passengers from the airport took the bus to Rotterdam Central Station, 26% travelled to Meijersplein and 9% of the passengers went elsewhere. The same pattern can be seen for travelers to the airport, 66% entered bus 33 at Central Station, 26% at Meijersplein and 8% elsewhere.

Table 5-3: OV-Chipcard data of Bus 33 in May 2015 specific for airport origin or destination

From	To	Workday	Saturday	Sunday	Total	%
Rotterdam Airport	Central Station	254	138	241	**7229**	**64**
Rotterdam Airport	Meijersplein	123	51	78	**3228**	**28**
Rotterdam Airport	Elsewhere	33	13	27	**893**	**8**
Central Station	Rotterdam Airport	221	138	232	**6491**	**66**
Meijersplein	Rotterdam Airport	101	34	46	**2521**	**26**
Elsewhere	Rotterdam Airport	27	18	25	**782**	**8**

Transfer passengers at Meijersplein

28% Of people travelling to the airport by public transport take bus 33 at metro station Meijersplein. People at Meijersplein could have taken the Randstadrail to Meijersplein or they came from the residential area 'Schiebroek'. To find out where these people came from, OV-Chipcard data of metro station Meijersplein must be further analyzed. This can be done by investigating transfer data at Meijersplein. This data only focusses on people travelling to the airport and transferring within the RET network. From the passengers of bus 33 from Meijersplein to the airport, 84% transferred there from the Randstadrail, the other 16% did not transfer but only entered the bus there.

Of the passengers that transferred at Meijersplein, the origin has been traced according to the OV-Chipcard data as can be seen in Appendix 10. Most people transferring at Meijersplein came from The Hague Central Station, followed by Rotterdam Beurs and Rotterdam Central Station. If a City Coaster would be available from Rotterdam Central Station to the airport, 82% of these people that transferred at Meijersplein could also travel to Rotterdam Central Station by train and take the City Coaster there without suffering because of a longer travel time. The other 18% of passengers transferring at Meijersplein, boarded the Randstadrail at stations where no faster connection to Rotterdam Central Station is available (e.g. Pijnacker, Berkel Rodenrijs). These passengers will not benefit from a City Coaster. Their travel time will slightly increase if they have to travel to Central Station first to take the City Coaster to the airport. Currently it takes 5 minutes by bus from Meijersplein with a transfer time of 9 minutes at Meijersplein (9292, 2017). The metro from Meijersplein to Rotterdam Central Station takes 6 minutes (9292, 2017), and a City Coaster to the airport 6 minutes without transfer time.

Monthly average and monthly demand

As could be seen in Figure 5-1, May 2015 was the busiest month at the airport. One would expect that the number of trips in May would be overestimated. However, other research conducted by RET (RET, 2016) shows a daily average bus demand to and from the airport of 610 trips from January 1, 2015 until June 30, 2015 (six months). The estimated 628 trips can be explained by the fact that in May many leisure passengers depart and arrive at the airport because of the holidays. It is less likely that these passengers take public transport to the airport if they travel with their family and/or have to take much luggage with them. Next to that, the monthly data of May 2015 contained errors, which could lead to an underestimation of the number of trips. For the further analysis, the average number of 610 trips per day to and from the airport will be used because this number is based on more observations for six months and the data does not contain errors.

Employees working around Rotterdam The Hague Airport

The OV-Chipcard data includes everyone taking bus 33 to and from the bus stop at the airport. This also includes employees working around Rotterdam The Hague Airport. Based on the modal split of airport passengers (12%) and the number of passengers from January 2015 to June 2015 (813905 passengers), it can be found that on average 535 airport passengers travelled by public transport to and from the airport per day. This indicates 535 trips to and from the airport every day by airport passengers. However, on average, 610 trips were made per day (RET, 2016). It is assumed that the trips left are people going to their work. Only 75 trips are left for employees working around the airport and boarding and unboarding bus 33 at the bus stop at the airport (seven-day average). Transforming this to working days (5 days), 105 trips per working day can be expected (e.g. 52 employees).

Near the airport terminal, two other bus stops (Vliegveldweg and Gatwickbaan) are interesting for employees. Analyzing the OD-matrices in Appendix 9 shows that these stops have a high demand from Rotterdam Central Station (on workdays 107 trips, e.g. 53 employees). Together with the 52 employees estimated before, a total of 105 employees using public transport can be estimated. The REBEL Group (Derksen et al., 2014) estimated a total of 2.500 jobs at the airport area. This indicates a current use of public transport from Central Station and Meijersplein by employees of 4.2%.

Current public transport use of airport passengers and employees

On a daily average, 610 public transport trips to and from the bus stop at the terminal have been estimated. 535 of these trips are made by airport passengers, the 75 trips left are made by employees. Per workday, this will be 105 trips. Other bus stops used by employees are accountable for 107 trips per workday. In total 212 work trips and 535 airport trips can be estimated by public transport. In total, 9460 trips are estimated to be made per day to the airport area (4460 airport passenger trips and 5000 work trips with all modes). Together, this implies a modal split of public transport of 7.9% for the area. In the next paragraph a modal shift to the City Coaster and with that to public transport, will be estimated.

5.4 Future public transport demand to and from the airport based on the transport model of Rotterdam

To estimate the future public transport demand, the transport model of the municipality of Rotterdam was used to estimate a modal shift to the City Coaster.

5.4.1 Model set-up

The version of the transport model of Rotterdam used for this research is version RVMK 3.1 with base year 2015, developed since 2013. This transport model has been set up to calculate possible changes in transport flows due to changes in the road infrastructure and public transport demand as well as changes in the social-economic structure (e.g. living, working and facilities). The model describes the number of movements for the modes car, bicycle and public transport (train, metro, tram and bus) for five different purposes (residential-work, business, residential-shopping, residential-education and other) for the morning peak (7.00 – 9.00), evening peak (16.00 – 18.00) and the remaining day. It is a static model, which means that the traffic demand for each time period is allocated to the network totally (Goudappel Coffeng, 2013-a).

The model is built with 5791 zones, each zone represents a specific area. Within Rotterdam the zones represent a 5-digit zip code, the zones outside Rotterdam have a lower level of detail. Each zone is represented with at least one centroid in the model. These centroids are connected to the network with a connector. Each centroid contains socio-economic data about the number of inhabitants, jobs, shops, etc. The zones and their corresponding centroids can be seen in Figure 5-3.

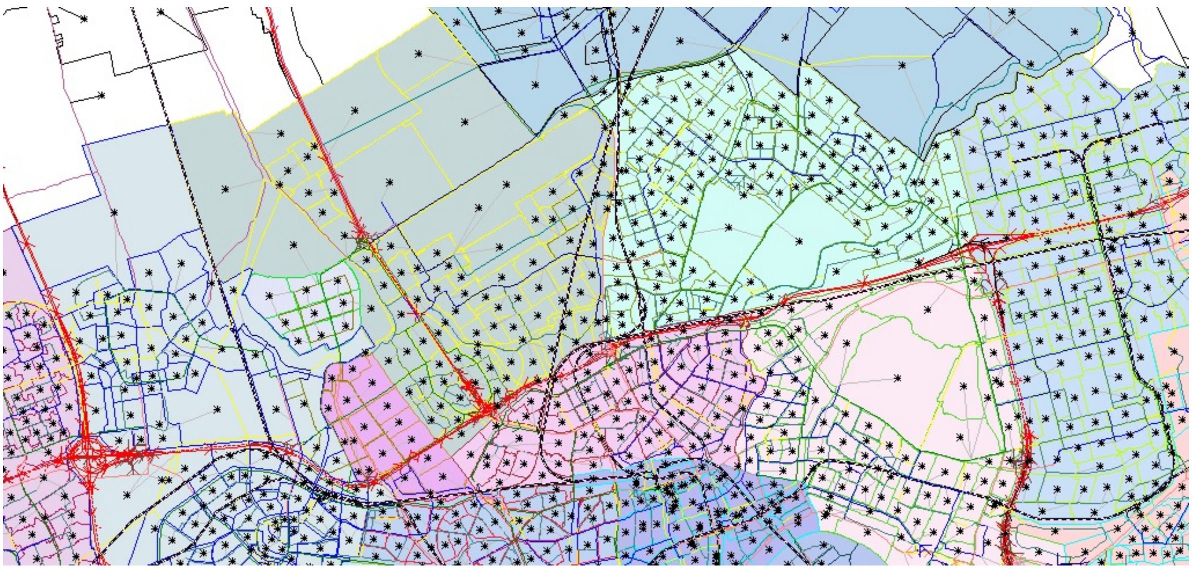


Figure 5-3: OmniTRANS model of Rotterdam, zones with their corresponding centroids (*) and the different networks (Highway A4, A13, A16 and A20 in red)

Based on the socio-economic data of each zone, the number of departing and arriving people can be estimated (trip generation). With a simultaneous gravity model (SGM), the accessibility of the destination (resistance) with the available transport modes will be considered simultaneously with the destination choice. This process can be seen in Figure 5-4.

The resistance is expressed in generalized costs. The model estimates a route for every mode and origin destination pair. For each route, the travel time and distance is used to calculate the generalized costs. The travel time costs are based on a value of time per travel purpose. The distance costs are based on fuel costs, parking costs, public transport fares, etc. In this way, the generalized costs are calculated per mode and purpose for every origin destination pair (Goudappel Coffeng, 2013-a).

A distribution and mode choice model are used to predict the number of trips per origin-destination combination. With distribution functions the mathematical relation between the willingness to make a trip and the corresponding resistance (generalized costs) can be described. The distribution functions differ per time period, purpose, mode and car accessibility (yes/no) (Goudappel Coffeng, 2013-a).

Next, the trips per origin-destination combination per mode can be assigned to the transport networks for every time period individually. For the morning and evening peak an iterative process is used with three iterations. It has been chosen to have three iterations because of the computation time of the model (30 hours on specially designed computers). After three iterations the model converges sufficient, including more iterations leads only to movement of traffic from one link or route to other links or routes and back. After the assignment of the trips to the transport networks the resistances (including congestion) are calculated again. Based on these new resistances and the willingness to make a trip process starts again (Goudappel Coffeng, 2013-a).

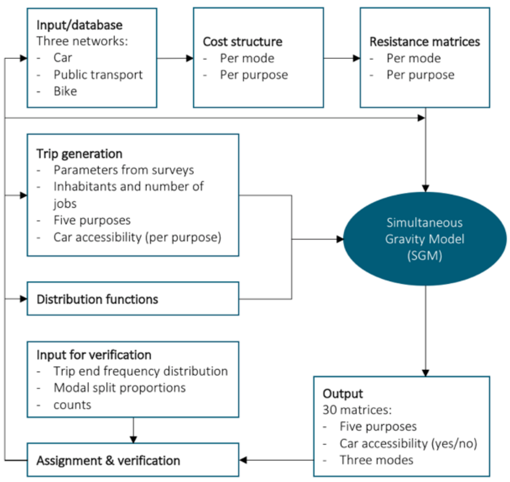


Figure 5-4: Simultaneously Gravity Model (SGM). Reprinted from: Goudappel Coffeng (2013-a)

5.4.2 Networks

In the transport model, different network layers represent the network of Rotterdam. The network has been set up with links and nodes. Each link has its own characteristics, such as maximum speed, capacity, accessibility per transport mode, etc. With the accessibility per transport mode it can be distinguished which mode can use the link, the rail network must only be used by trains for example. In the model, the main distinction made between public transport modes is train, tram, metro and bus. The public transport networks of the Rotterdam model can be seen in Figure 5-5.

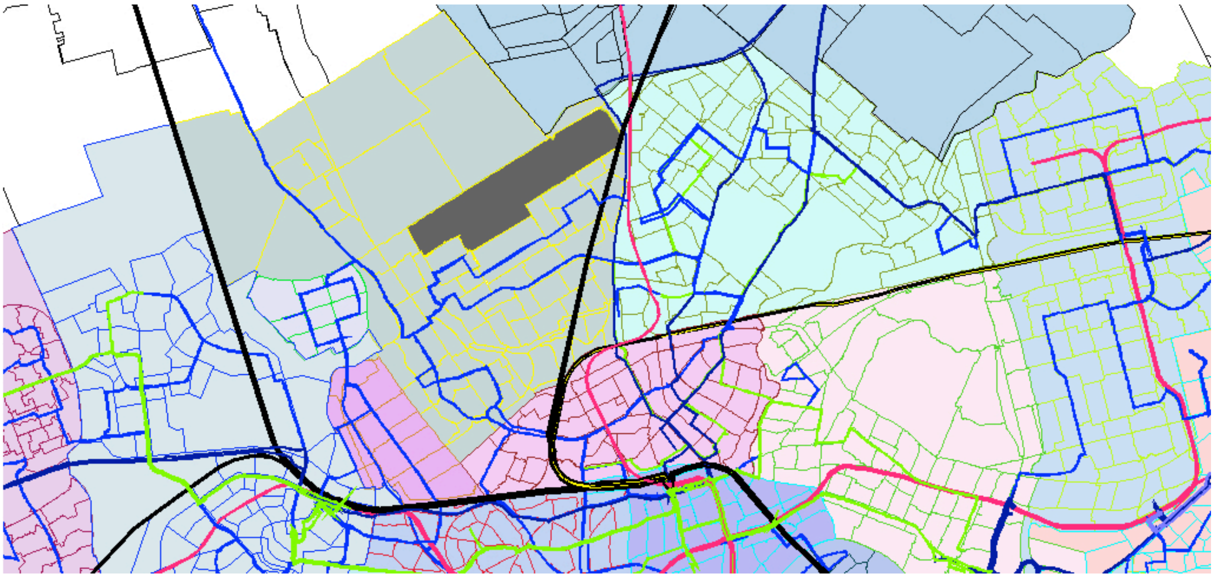


Figure 5-5: OmniTRANS model of Rotterdam, Public transport networks. Black: train, red: metro, blue: bus and tram.

5.4.3 Rotterdam The Hague Airport in the Rotterdam model

Rotterdam The Hague Airport is located on the northern part of the city as can be seen in Figure 5-5 (dark grey area). Rotterdam The Hague Airport has its own zone (1600) in the model because of the non-uniform production and attraction. Because the production and attraction cannot be estimated based on the socio-economic data, the production and attraction of these zones is a fixed input for the model. Other areas with non-uniform production and attraction are for example hospitals, the zoo and touristic hotspots (Goudappel Coffeng, 2013-a). The zones near the airport zone are also interesting for this research, here the offices around the airport are located. These are the zones 1980, 1981 and 2038 as can be seen in Figure 5-6. The socio-economic data of these zones can be found in Appendix 11.

Figure 5-6: OmniTRANS model of Rotterdam, zoom-in of the airport zones.

The public transport network used for the base year 2015 version of the model dates from the 2013 timetable. In this timetable, bus 33 is included. However, this bus terminates at the terminal and will not ride until station Meijersplein. Meijersplein is connected to the airport with a shuttle bus which has a frequency of twice an hour. Next to these busses, bus line 41 drives with a frequency of twice an hour from Schiedam Centrum to Rotterdam Noord via Rotterdam The Hague Airport. Currently, this bus is not operated anymore.

Adaption of the model to the current situation

To estimate a modal shift to the City Coaster the current modal split in the model must be equal to the modal split based on the modal split mentioned in section 5.3.2. Because the modal split according to the model is not corresponding with the modal split mentioned in section 5.3.2 and the public transport demand in the model is not corresponding with reality, the model has to be adapted. First bus line 41 has been removed from the model and the frequency of bus 50 has been increased to 6 times hour (same as bus 33). Second, zone 1600 (the airport) can't be reached by bike anymore. This because in the initial model the zone had a bike share of 10%.

Modal split of the airport area without City Coaster

Based on the abovementioned adaptations the model split of the relevant zones has been estimated in the current situation according to the model. This includes airport passengers and employees of the companies. The public transport modal split according to the model has been estimated to 7.5% which is in line with the modal split as mentioned in section 5.3.2 of 7.9%. It should be noted here that this is the modal split of the airport and business zones together. As mentioned before, the airport zone is a zone with non-uniform production and attraction and in which only two modes (car and public transport) are considered. By considering only this zone, the modal split is not in line with the modal split as estimated in section 5.3.1 and 5.3.2. This can be explained by the significance in the model, the airport zone is only one zone of 5791 zones in the whole model. By selecting more zones, the significance increases. Therefore, the airport region as a whole has been considered (J. Rijsdijk, personal communication, March 15, 2017). According to the model, the car share of the region is 83.8%, for bike this is 8.7%.

Adaption of the model to the City Coaster

To estimate a modal shift to the City Coaster, this City Coaster is added to the network. The design of the City Coaster in the network is based on the design in Chapter 4. Next to that, the frequency of the current bus has to be decreased, especially between Meijersplein and the airport. The frequency of bus 33 has been set to two times per hour. To add the City Coaster, a new direct transit line was implemented between the airport and central station. The travel time of the City Coaster has been set to six minutes, according to paragraph 4.2. The frequency of the City Coaster was set to 60/hour which can be achieved with 15 vehicles, according to paragraph 4.3.

Modal split of the airport area with City Coaster

Again, with the abovementioned adaptations the model has been estimated. The modal split with City Coaster according to the model is 6.5% for bike, 18.1% for public transport and 75.4% for car.

5.4.4 Discussion of the outcomes of the Rotterdam Model

The modal split of public transport for the airport area increases from 7.5% to 18.1% by implementing a City Coaster. The shift mostly occurs from car to public transport. However, the bike share decreases from 8.7% to 6.5% which is a negative impact of the City Coaster. It should be noted here that the model is a simplification of reality. In the model, there are only three modes available, car, public transport and bike. For the airport zone only two modes are considered, car and public transport. In real-life, people use other modes to the airport as well (e.g. taxi, rental cars). These are not modelled with the model. The mode public transport is not further specified, no alternative specific constants for the public transport modes are used because it is not expected that this has a major impact on the results of the model (J. Rijsdijk, personal communication, March 15, 2017). So, there is no distinction made between a train or a bus, the only distinction made is based on the travel time. Next to that, airport passengers have a very specific travel purpose which is not specifically modelled with the model. The airport passengers have the purpose 'other' which is also used for people going to a hospital or the zoo. To find out if airport passengers would use a system as the City Coaster to the airport, interviews were conducted which will be described in the next sub paragraph.

5.5 Passenger interviews at the airport

To get insight in the objectives and requirements of the passengers and to estimate if they would use a system as the City Coaster, interviews with the passengers were conducted via the Wi-Fi network at the airport. The questions asked are attached in Appendix 12. The data gathered from the interviews consists of mainly categorical data.

5.5.1 Sample size

To calculate the sample size for the airport population, the equation of Cochran has been used because of the large population size (Israel, 1992, Ortúzar & Willumsen, 2011-b and Ampt et al., 1995):

$$n = \frac{Z^2 pq}{e^2}$$

where n is the sample size, Z is the Z-score according to the confidence level, e is the confidence interval, p is the estimated proportion of an attribute that is present in the population, and q is equal to 1-p. For a 95% confidence level, Z is equal to 1.96. The proportion of an attribute has to be estimated. Unfortunately, this value is not known before conducting the interview. Therefore, the highest value of pq is used which is equal to 0.25 in case of 50% proportion. The desired confidence interval is 5%. With these values, the sample can be estimated to 384. In total, only 290 passengers were interviewed. The corresponding confidence interval is according to the equation of Cochran equal to 5.75%. This confidence interval is accepted due to time restrictions. This confidence interval indicates that the answers given is by an interviewee could be 5.75% more or less than the answer provided.

5.5.2 Population sample

Figure 5-7 shows the modal split of the population sample based on the interviews. As can be seen, car (parked) and car (Kiss+Ride) have the highest share, followed by public transport. Comparing these results with the current modal split of the airport (see Figure 5-2 and the values in red), the shares are not the same. This can be explained by changes over time or because the population sample is not representative regarding transport mode for the entire population. Because the interviews are conducted in only two weeks, it is assumed that the population sample is not representative regarding transport mode. Therefore, the interviews will be scaled regarding their transport mode so the corresponding share will be the same as in the entire population.

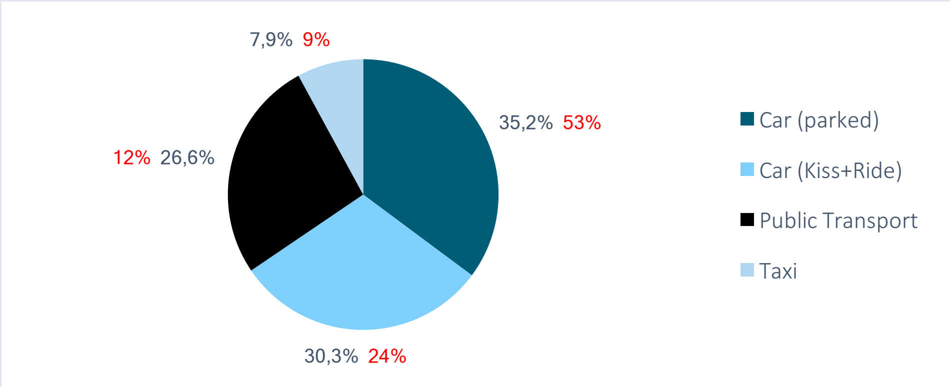


Figure 5-7: Modal split of the population sample

5.5.3 Modal shift to the City Coaster according to the interview

As stated by Adell et al. (2014), there is no straightforward method to estimate people's acceptance of a new system. Therefore, it has been chosen to ask people if they would use public transport to the airport if there would be a direct connection available between the airport and central station which would take 6 minutes. This because the people are familiar with other public transport modes and their answer will not be biased because of the City Coaster. Next, it was asked if they would also use it if this system would be a City Coaster (an explanation and picture of the City Coaster were included). Because the City Coaster has not been implemented (yet), a method as for example Van der Laan et al. (1997) can't be used. With this method, the respondents are asked to rate bipolar items (e.g. usefull – useless, pleasant – unpleasant, bad – good, nice – annoying, etc.) However, according to Adell et al. (2014) it is advised to use more than one way of measuring acceptance. Therefore, a simple other question has been added to the survey in which the respondent is asked if they would recommend a system as the City Coaster to family and friends (based on the information provided in the survey).

As mentioned before, the sample is not representing the population regarding mode choice. Therefore, a modal shift to the City Coaster will be estimated per transport mode. This information can then be translated to the entire population. Of the car (parked) travelers, 36% responded that they would travel by public transport if this connection would be available. For car (Kiss+Ride) this was 44%, and 56% of the taxi users would travel by public transport if there would be a connection available of 6 minutes.

Of the 160 interviewees replying that they would travel by public transport if this connection would be available, only six respondents would not use a system as the City Coaster. If the passengers would do as they say they would do according to the interview, the public transport modal split of Rotterdam The Hague Airport would increase to 46.9%. Amsterdam Airport Schiphol, with a perfect train accessibility, has currently a public transport modal split of 42% (Royal Schiphol Group, 2017). With the City Coaster, an extra transfer at Central Station to the City Coaster is still required, the estimated share seems therefore not realistic. This can be explained by Hammersley & Gomm (2008) and Fisher (1993). According to Hammersley & Gomm (2008), it should be taken into account that what people say in a survey will be shaped by the questions that were asked, by what they think the interviewer wants and by what they believe the interviewer would approve or disapprove. Fisher (1993) identifies a social desirability bias (SDB) in interviews and surveys. The SDB describes the tendency to present oneself in the best possible light (Fisher, 1993). This bias is most likely to occur in responses to socially sensitive questions (King & Brunner, 2000). In the case of the airport passenger interviews, using public transport is social desirable which could make the answer to this question biased. Therefore, the size of the social desirability bias must be estimated. Steenkamp et al. (2009) estimated that in marketing, 25-40% of the responses are influenced because of a social desirable bias. This estimate is not specific for mode choice questions, this specific information is unfortunately not available in literature. However, this estimate gives an idea of the social desirable bias which will be applied to the interview answers. Therefore, it is assumed that 35% of the responses are influenced because of the social desirable bias. With this, the modal split for public transport would increase from 12% to 34.7%.

5.5.4 Other descriptive statistics

From the interviews at the airport, a large set of descriptive statistics (age, travel purpose, transport mode, departure time, etc.) can be derived of which the relevant statistics will be discussed in this section. In Appendix 13 the cross tables regarding these questions are attached, in Appendix 14 other descriptive statistics are attached.

Public transport passengers

Interviewees currently travelling by public transport to the airport do this mainly because it is convenient, they don't have to pay parking fees and because they don't have a car or driving license. The price of public transport, road congestion and car fuel cost are minor reasons to choose for public transport. On average, the people travelling by public transport rate it 8.2 on a scale from 1 to 10 with a standard deviation of 1.4. However, there is room for improvement, only 35% of the public transport passengers is satisfied with the current public transport. Most complaints are regarding travel time and transferring with public transport. Price, comfort, reliability, frequency and the number of stops are less heard complaints.

Price of a single trip with the City Coaster

People who would use the City Coaster would on average pay € 3.91 with a standard deviation of € 1.95. The median (middle value) and mode (most occurring value) is € 3.00. Passengers already using public transport to the airport are willing to pay on average € 3.74 compared to people using other modes € 4.04. The answers were based on the current public transport tariff (€ 1.70) and a taxi ride (€ 20.00).

The City Coaster compared to other public transport modes

Compared to other public transport modes, the City Coaster was most preferred. Based on a scale from 0 to 10 the interviewees had to choose a score for the conventional system (bus, tram, metro or train) (score 0) or the City Coaster (score 10). A score of 5 would indicate no difference between the conventional system and the City Coaster.

- Compared with a bus, the City Coaster scored an 8.2 (S.D. = 1.9)
- Compared with a tram, the City Coaster scored a 7.9 (S.D. = 1.9)
- Compared with a metro, the City Coaster scored a 7.0 (S.D. = 2.4)
- Compared with a train, the City Coaster scored a 6.9 (S.D. = 2.5)

5.5.5 Pearson's Chi-Square test

One can imagine that the current transport mode of the interviewees has influence on the question whether or not to travel with public transport from Central Station to the airport in 6 minutes. In other words, is there a relation between transport mode and the answer to the public transport question. This relationship can be identified with a Pearson's chi-square test. The chi-square test is based on the idea of comparing the frequencies observed in certain categories to the frequencies expected to get in those categories by chance (Field, 2009). Basically, what is done with the Pearson's chi-square test, is standardizing the deviation for each observation. Adding these standardized deviations together results in Pearson's chi-square (Field, 2009):

$$\chi^2 = \sum \frac{\left(observed_{ij} - model_{ij}\right)^2}{model_{ij}}$$

The chi-square test has been chosen because only categorical data is available. Table 5-4 shows the results of the Pearson chi-square test conducted in statistical software SPSS version 24. If the test is significant, there is a relationship between the two variables. Appendix 15 shows the results of the Pearson's chi-square tests in SPSS.

Table 5-4: Pearson's chi-square test

Variable 1	Variable 2	Pearson's chi-square	Significance	Significant?
With Public Transport	With City Coaster	198.6	0.000	Yes
Travel Companion	With Public Transport	35.9	0.000	Yes
Departure Time	With Public Transport	7.0	0.323	No
Transport Mode	With Public Transport	61.6	0.000	Yes
Travel Pupose	With Public Transport	8.4	0.004	Yes
Age	With Public Transport	29.1	0.000	Yes
Age	Transport Mode	38.5	0.000	Yes
Departure Time	Transport Mode	20.0	0.331	No
Transport Mode	Travel Purpose	15.9	0.001	Yes

The significance value has to be smaller than 0.05 (Field, 2009). If it is smaller than 0.05 the hypothesis that the variables are independent can be rejected. In other words, the variables are in some way related. This means that if an interviewee is asked whether he/she would use the 6 minute-public transport connection to the airport, this depends on the age, current transport mode, travel companion and travel purpose. There is no relation found between the departure time and the transport mode and between the departure time and the willingness to use public transport.

5.5.6 Logistic Regression

With the Pearson's chi-square test only a relation between two variables can be estimated. To predict which category a person belongs to, regression analysis must be applied (Field, 2009). Logistic regression must be used because the interview data consists mainly of categorical data. With the obtained data, it can be predicted whether a person would travel with the City Coaster or not (yes/no), based on the predictor variables. The probability of Y occurring can be calculated with predictor variables X and betas b by (Field, 2009):

$$P(Y) = \frac{1}{1 + e^{-(b_0 + b_1 X_1 + b_2 X_2 + b_n X_n)}}$$

Approach

The logistic regression has been analyzed in SPSS version 24. Because the question to the passenger's age has not been filled in by every passenger, cases in which no answer was provided were removed from the dataset. Other variables included are travel purpose, departure time, travel companion and transport mode. These variables were all included as categories which are attached in Appendix 17. The logistic regression has been analyzed based on the backward conditional method. With this method, all variables (age, travel purpose, departure time, travel companion and transport mode) are included in the regression in the first step. In the second step, the least scoring variable will be excluded based on the log-likelihood ratio. This process continues until the parameter estimates do not change more than 0.001 or all variables are excluded (Field, 2009).

Results

The betas of the logistic regression analysis are almost never significant, except for the categories in variable transport mode. Because of the insignificance of the betas it is not possible to make statements regarding the strength of the category and the model cannot be used to estimate the use of the City Coaster. However, based on the model, other conclusions can be drawn. Based on the signs of the betas it can be concluded that younger people tend to use the City Coaster more than elder people. The same holds for business people compared to leisure travelers. For travel companion, it can be concluded that people traveling with their partner would use the City Coaster less compared to someone traveling alone (reference). Next to that, people traveling with friends or colleagues have a higher preference for the City Coaster compared people traveling alone. Last, people traveling with car or taxi would use the City Coaster less compared to people travelling with public transport. This makes sense because most people travelling with public transport would also use the City Coaster (see the results of the Chi-square test in Appendix 15). The logistic regression output of SPSS can be found in Appendix 18.

5.6 Growth of the airport and office buildings

Currently, 1.7 million passengers travel via the airport yearly and 2500 labor places are available at the airport area. Further expansion of flights is within the current noise restrictions not possible (RTHA, 2017-a). Nevertheless, the airport provides around 25 percent of its noise capacity to the emergency and police helicopter of Rotterdam. By moving them to another location this capacity can be used for commercial flights. Because of this, the airport expects to grow from 1.7 million passengers in 2016 to a maximum of 2.3 million passengers in the future (S. van der Kleij, personal communication, March 28, 2017). Further expansion in the near future is not expected because there is no public support for further expansion of the noise restrictions (Schrijnen, 2017). The Dutch government focusses in its airport policies mainly on the international airport Schiphol. Currently, Schiphol is allowed to increase the number of flights to 500,000 arriving and departing flights per year. Eindhoven and Lelystad are also allowed to expand. According to the government, they have to deal with flights that do not necessarily have to land at Schiphol (Rijksoverheid, n.d.). The role of Rotterdam The Hague airport is not mentioned in the policy of the government. As stated before, it is currently restricted by its noise restrictions.

According to the site allocation plan of the airport area, in total 38,500 square meter office space can be developed before 2023 of which 19,500 Square meters has been developed already. Another 10,000-square meter is currently in the planning phase and the other 9,000 square meters can be developed in the near future. Assuming twenty square meter office space per employee, a growth of 500 and 450 jobs can be expected respectively (C. Lonis, personal communication, April 6, 2017).

5.7 Demand scenarios

Based on the transport model, the passenger interviews and growth scenarios of the airport and the surrounding office spaces, demand scenarios can be made. It is distinguished between growth in modal split and growth of passengers/employees for the airport and the employees working in the area. Table 5-5 and Table 5-6 show the number of trips by passengers and employees based on the modal shifts according to the current situation, the transport model and the passenger interviews. As can be seen in Table 5-5 and Table 5-6, the columns represent different growth scenarios of the airport and the office space respectively.

Table 5-5: Trips of daily passengers at the airport using public transport on an average weekday

Daily Passengers	4460	5575
12% (current)	535	669
18.1% (model)	807	1009
34.7% (interviews incl. SDB)	1548	1935

Table 5-6: Trips of employees in the area using public transport on an average working day

Employees	5000	6000	6900
4.2% (current)	210	252	290
18.1% (model)	905	1086	1249

With this information, 36 scenarios based on the modal split and growth can be estimated. However, one can imagine that if the modal split of passengers increases, the modal split of employees will increase as well. It is unlikely that the City Coaster would only attract airport passengers. Next to that, Schiphol Real Estate is currently planning the expansion of its office space at the airport, it is therefore not expected that the number of employees remains 2500. By excluding these scenarios, only 9 scenarios are left as can be seen in Table 5-7.

Table 5-7: Demand scenarios for the City Coaster

Scenario	Modal Split passengers	Modal Split employees	Airport passengers per day	Employees trips per day
S1 (current)	12%	4.2%	4460	5000
S 2.1	18.1%	18.1%	4460	6000
S 2.2	18.1%	18.1%	4460	6900
S 2.3	18.1%	18.1%	5575	6000
S 2.4	18.1%	18.1%	5575	6900
S 3.1	34.7%	18.1%	4460	6000
S 3.2	34.7%	18.1%	4460	6900
S 3.3	34.7%	18.1%	5575	6000
S 3.4	34.7%	18.1%	5575	6900

Ortúzar & Willumsen (2011-d) advice to make pessimistic and optimistic scenarios for demand planning. Next to that, a neutral scenario will be used which is not optimistic nor pessimistic. The pessimistic scenario underlies a public transport modal split of 12% passengers and 4.2% for employees (current situation). The optimistic scenario underlies a modal split of passengers of 34.7% and 18.1% of employees and in the neutral scenario both have a modal split of 18.1%. The modal split of 46.9% will not be taken into account because it is unlikely that the modal split increases to 46.9%.

5.7.1 Pessimistic scenario (current situation) (S 1)

The pessimistic scenario is estimated based on the current situation in which the airport passengers have a public transport modal split of 12% and employees of 4.2%. Per day, 535 airport passenger trips and 210 trips by employees can be expected. Per week this will induce 4800 trips to and from the area.

5.7.2 Neutral scenario (S 2.X)

In the neutral scenario, a public transport modal split of 18.1% for the passengers and the employees is expected. If the airport is not allowed to grow and the number of employees increases to 3000 (S 2.1), 1893 trips to and from the area can be expected per work day. Per week, 11,079 trips would be made to and from the area. If the airport is allowed to expand, additional 209 daily trips can be expected by airport passengers (S 2.3).

5.7.3 Optimistic scenario (S 3.X)

The optimistic scenario underlies a passenger modal split of 34.7%, according to the interviews (including SDB) and 18.1% use of public transport by employees. Without growth of the airport, 1548 and 1086 trips can be expected on a daily basis to and from the airport (S 3.1). If the airport expands and the office space will be developed totally, 1935 and 1249 trips can be expected on a daily basis.

6 Feasibility study of the design

The model of Feitelson & Salomon (2004) describes interacting factors to estimate the feasibility of a transport innovation, based on a technical, social and political feasibility. The model can be seen in Figure 6-1 (same as Figure 1-2). The interacting factors in case of the City Coaster are experts from the roller coaster and automotive industry, the interests of public transport companies and the advantages and disadvantages for the users of the City Coaster as well as for society compared to conventional transport modes.

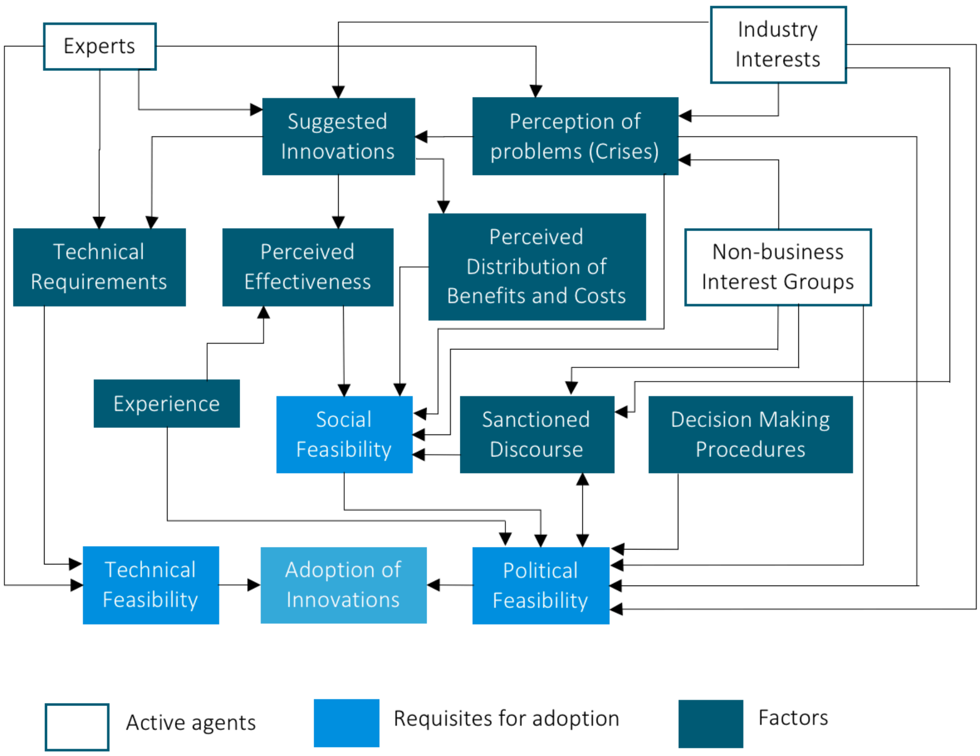


Figure 6-1: A political economy model of transport innovations. Source: Feitelson & Salomon (2004)

The three requisites for adoption, technical, social and political feasibility of the City Coaster will be described below.

6.1 Technical feasibility

According to the model in Figure 6-1, the technical feasibility depends on the technical requirements and expert judgement. The requirements are discussed in Chapter 3 and based on these requirements and literature research a design has been made for the City Coaster between the airport and Central Station. To analyze the feasibility of this design experts were consulted to give their advice regarding the City Coaster. It has been distinguished in three components: the roller coaster track itself, the construction of the track and the automated vehicles on the track.

6.1.1 The roller coaster track

For the technical feasibility of the roller coaster track the Dutch roller coaster designing firm VEKOMA has been consulted (J. Philippen, personal communication, May 11, 2017). According to Philippen, many designs of the roller coaster track are possible, from a gravity based track to a horizontal track with a track-based or vehicle-based drive. A gravity based track is known from the current roller coasters in theme parks, the vehicles are lifted to a dedicated height and based on gravity they run until the station. Track-based or vehicle-based drive systems have the advantage that the vehicles are highly controllable (J. Philippen, personal communication, May 11, 2017) compared to a gravity based track. The advantage of vehicle-based drive system is that the track can be kept as simple as possible, maintenance of the track can be kept to a minimum which has a positive impact on the capacity of the system. The disadvantage of a vehicle based drive system is that the track can have a maximum gradient of 5% (J. Philippen, personal communication, May 11, 2017).

6.1.2 Construction of the track

Because the track between the airport and Central station is mainly located above street level, a construction to hold the roller coaster track and the vehicles has to be designed. Therefore, the construction department of Witteveen+Bos was asked if it is possible to design a construction which can hold the roller coaster track and the vehicles at a height of (on average) five meters above ground level. This is feasible, however, the construction as shown on the front page of this report is not able to hold the weight of the roller coaster track and the vehicles. As a rough estimate, a support column with a diameter of 50-75 cm is required every 25 meters to hold the construction and the vehicles.

6.1.3 Automated vehicles on the track

For the automation of the vehicles Carlo van de Weijer, director strategic area smart mobility at TU Eindhoven, has been consulted. According to van de Weijer, automated vehicles on a public road in a city is with the current technology not possible. However, having a dedicated infrastructure for these vehicles on which the vehicles are attached, is technically feasible. Van de Weijer advices to choose for a 'dumb' infrastructure with intelligent vehicles. This shift can currently be seen in the automotive but also in the rail sector (e.g. ERTMS). In this way, the system remains flexible and also cheaper. Using current cooperative vehicle to vehicle communication (V2V), the City Coaster must be able to fulfill its tasks (C. van de Weijer, personal communication, May 15, 2017). The feasibility of the cooperative V2V technology has been proven in the Grand Cooperative Driving Challenge held in 2016 in Helmond, the Netherlands. In this challenge, the vehicles had to operate in two scenarios; cooperative platoon merge and cooperative intersection passing (Englund et al., 2016). The scenarios showed in this challenge are more extensive than the tasks of the City Coaster. Collisions must be prevented and the vehicle has to know where to stop in the stations. According to van de Weijer, collisions can be prevented using the V2V technology, stopping in the stations can be achieved using technology which communicates in the station to the vehicle where to stop.

6.2 Social feasibility

The advantages and disadvantages for the users and society play the most important role in analyzing the social feasibility. Social feasibility is a function of public perception of problems and the perception of the effectiveness of the proposed innovation in addressing these problems (Feitelson & Salomon, 2004). The advantages and disadvantages for the users and society are monetized using a cost benefit analysis. Figure 6-1 shows that the social feasibility depends on four factors, the perception of problems, the sanctioned discourse, the perceived effectiveness, and the perceived distribution of benefits and costs.

6.2.1 Perception of problems

The perception of problems can be explained according to the stakeholder analysis in Chapter 3. Most stakeholders agree that the current public transport system does not meet the expectations. The use of public transport to the airport should be higher and the travel time should be shorter. The municipality of Rotterdam mentioned that the current bus system is not that bad, however, they acknowledge the low modal split of public transport. Next to that, based on the airport interview data, it has been found that only 35% of the public transport passengers is satisfied with the current public transport, the other 65% sees room for improvement.

6.2.2 Sanctioned discourse

A sanctioned discourse could not be identified based on the stakeholder analysis. The stakeholders agreed that an on-demand system is required to cope with the high peak demand of the airport. The reason why no new system has been implemented yet, is that a viable business case is hard to establish.

6.2.3 Perceived effectiveness

The interviews with the passengers at the airport showed that the passengers respond positively towards the City Coaster. Only six people willing to use public transport (n=160), would not use a City Coaster. During the participation of Witteveen+Bos in the 'Rotterdamse Infrastructuur Uitdaging' the 'Algemeen Dagblad', a Dutch national newspaper, posted a poll on its website in which the readers were asked to choose which participating idea out of five they preferred most. 45% Of the voters voted for the City Coaster (Algemeen Dagblad, 2016).

Cook et al. (2004), investigated the public acceptability of the ULTra PRT test system including elevated tracks. The results showed that the respondents were in favor of the system without driver. However, only 75% of the respondents did not have any issues with the elevated track, 25% was not sure about it. As part of the CityMobil project of the European Commission, the implemented ULTra PRT system at London Heathrow was compared to the previous bus system (Bly, 2011-b). The research showed that the PRT system scored much better on all criteria compared to the bus. The researches show that a PRT system is accepted and preferred by passengers compared to a bus system. This also follows from the interviews at the airport. People preferred the City Coaster above other public transport modes. Next to that, it can be concluded that the City Coaster has a positive effect on the modal split of the airport passengers. Whether this effect is enough to have a positive cost benefit analysis will follow in the next section.

6.2.4 Distribution of benefits and costs

The distribution of benefits and costs is estimated based on a cost benefit analysis (CBA). In the Netherlands, the CBA has become a major tool for policy analysis. The aim of a cost benefit analysis is to derive the costs and benefits for all actors affected by the policy (Rietveld, 2013). The implementation and operating costs of the City Coaster will be estimated based on the design. The operating benefits will be calculated for different demand scenarios, as estimated in section 5.7. The literature used for the cost benefit analysis is the 'Algemene Leidraad voor maatschappelijke kosten-batenanalyse' (Romijn & Renes, 2013) and 'KBA bij MIRT-verkenningen' (Ministerie van Infrastructuur & Milieu, 2012). This cost benefit analysis will be used to evaluate the scenarios of section 5.7. The scenarios are compared with a null alternative in which no City Coaster is implemented.

Investment costs

Based on a cost estimation at Witteveen+Bos the investment costs of a two-way track with a height of 5 meters including the construction are estimated at 4 million/km. For the stations at Central Station and the airport it is assumed (based on a benchmark with railway, tram and metro stations according to the 'Waaier van Brogt' (Goudappel Coffeng, 2013-b)), that the stations investments are €1,000,000 per station. The vehicle investment costs of a PRT system have been estimated by van Zuylen et al. (2010-b) to € 136,000 in 2010. However, taken into account the current electric vehicle market in which it is possible to buy a Tesla Model S vehicle for 78,000 Euro (Model S 60), this estimate seems not realistic in the current market anymore. Therefore, the vehicle investment costs are assumed to be 100,000 Euro.

Operating costs

The operating costs consist of the maintenance of the track, the maintenance of the vehicles, personnel costs and energy costs of the vehicles. The maintenance of the track has been estimated at 1% of the investment costs (Goudappel Coffeng, 2013-b). The maintenance of the vehicles has been estimated by van Zuylen et al. (2010-b) to five percent of the investment costs. To operate the system, employees are required (see Appendix 19). The energy costs were already estimated in section 4.3.

Operational benefits

The operational benefits of the City Coaster are determined by the fee for the airport travelers and for the employees of the area. According to the stakeholder analysis, the employees should pay the usual public transport tariff of Rotterdam, incidental (airport) travelers could be charged a higher fare. The interviews with the airport passengers showed that people are willing to pay on average € 3.91 per single ride (see section 5.5.3). However, the median and mode have been estimated to € 3.00. Therefore, a transport fee of € 3.00 per passenger is used in the calculation of the operational benefits.

Direct effects

Effects on the market where a policy is implemented are called direct effects (Romijn & Renes, 2013). For infrastructure projects such as the City Coaster, the project enters the transport market and effects the users, owners and operators in this market.

Distribution of modal shift

Table 6-1 shows the distribution of modal shift passengers. The current modal split is based on Brands et al. (2015). The modal shift to the City Coaster is based on the interview data. Combining both, the distribution of modal shift passengers can be estimated. For example, 55% of the modal shift passengers are parked car passengers.

Table 6-1: Distribution of airport passenger' modal shift

Mode	Current modal split	Shift to City Coaster incl. SDB	Distribution of modal shift passengers
Car (parked)	53%	23.6%	55.0%
Car (Kiss+Ride)	24%	28.8%	30.4%
Rental car	1%		
Public transport	12%	100%	
Taxi	9%	36.7%	14.5%
Other	1%		

The current public transport modal split of employees is 4.2% according to the OV-Chipcard data. According to the transport model of Rotterdam, this increases to 18.1% with the City Coaster. The bike split decreases with 4.4% under employees.

Table 6-2: Distribution of employee modal shift

Mode	Current modal split	City Coaster modal split
Car	79.2%	69.7%
Bike	16.6%	12.2%
Public Transport	4.2%	18.1%

Value of time (VOT)

The travel time gain can be calculated using a value of time (VOT) for airport passengers and employees in the area. The VOT of people on their way to an airport was comprehensively studied by Landau et al. (2015). This research has been conducted under 1,260 passengers traveling on flights between different origin destination pairs throughout the United States. In the research, the ground access and egress time is estimated on $16.95 for leisure and $18.60 for business passengers. Based on the share of business travelers at Rotterdam The Hague Airport, a VOT of €15.50 has been estimated. For commuting passengers of the City Coaster an average value of time of 10€/hour (KiM, 2013), has been used. For the drivers of Kiss & Ride passengers, a value of time of 7.5€/hour has been chosen according to KiM (2013). This is the value of time of car users with travel purpose 'other'.

Travel time gain of airport passengers

For current public transport passengers, the travel time gain has been calculated. Because of the good car accessibility of the airport region, the travel time by public transport increases for every car user changing to the City Coaster (Appendix 21). However, according to the passenger interviews, passengers would use public transport to the airport if a City Coaster would be available. This can be explained based on a microeconomic theory (Donnea, 1971) in which individuals make choices to maximize their own profit. For this research, the out-of-pocket costs of travelers and the travel time costs have been considered in the microeconomic theory which is attached in Appendix 21.

Travel time gain of employees

Employees currently using public transport benefit from the City Coaster because their travel time to the airport area decreases by 15 minutes. For the employees changing to the City Coaster, no information about their origin is known. The transport model of Rotterdam cannot be used because the airport region as a whole had to be considered. The travel time gain or consumer surplus of the shifting employees can therefore not be estimated. By not taking into account the travel time gains or the consumer surplus of the employees the benefits will be underestimated.

Government tax income

In the Netherlands, the government collects taxes on fuel which has been estimated on 3.8 Euro cent per kilometer in 2020 (Bakker & Zwaneveld, 2009). People parking their car at the airport, Kiss & Ride passengers and employees generate less tax income for the government if they shift to public transport. Because no data is available of the employees, it is assumed that they travel on average 22 kilometers, based on Kalter et al. (2010). This estimate dates from 2008 and is a national average.

Other direct effects

Direct effects that will not be considered in the cost benefit analysis are avoided parking costs, congestion on roads towards the airport and comfort and reliability of the City Coaster. These effects will be neglected because available space at the airport is not scarce, the spread airport demand will not induce less congestion and people using the City Coaster still have to use other public transport to Central Station respectively.

Indirect effects

Direct effects have impact on other markets in an economy. These impacts on other markets are called indirect effects (Romijn & Renes, 2013). In the cost benefit analysis, the markets in which these indirect effects occur, have to be demarcated. An indirect effect is for example employment and airport choice. These indirect effects are hard to estimate and are therefore out of scope for this research. On the other hand, one can argue that these effects are redistributed from other locations and are therefore no benefit for society. People changing their job location had their job somewhere else before. People choosing Rotterdam The Hague Airport chose another airport before. Only in case of a disturbed market, these effects have to be considered as indirect effect (Hoefsloot & de Pater, 2011).

External effects

Effects that do not have an impact on a market are called external effects (Romijn & Renes, 2013). The impact of projects on for example environment, nature and safety are difficult to express in a monetary value because there is no market for these components. The external effects of the City Coaster will be discussed below.

Emissions

By implementing the City Coaster, the use of Bus 33 will decrease. The emissions of this bus will then be lower. Per traveler kilometer, a price of € 0.0175 is used to estimate the monetary value of these emissions (van Essen et al., 2008). This value is a weighted average for public transport busses in 2020, including upstream and wear emissions. For an average car, this value is 0.0092 Euro per traveler kilometer. Passengers brought to the airport (Kiss & Ride and Taxi) have twice as much emissions because the driver has to drive back to his/her origin. On the other hand, people changing to public transport induce additional emissions caused by public transport which are additional costs for society. Van Essen et al. (2008) estimated these emissions for all public transport modes per traveler-kilometer. Because it is not known which mode people take to Central Station, an average value of all modes is assumed to be 0.005 Euro per passenger-kilometer (based on van Essen et al., 2008). Emissions of the City Coaster are assumed to be zero (Groot, 2004) because the vehicles can run on green energy.

Road safety

In every scenario except scenario 1 a modal shift occurs. This implies that the distance traveled by car decreases. This can have a positive impact on the road safety which should be considered as a benefit. However, for the City Coaster it is expected that the increase of road safety has no major benefits, therefore, it will not be considered.

Noise

Noise emissions have impact on the house prices and on the people's health affected by the noise emission (Ruijgrok, 2011). These are societal costs that should be considered in the cost benefit analysis. Based on literature research the noise emissions of a roller coaster and electric vehicles could be found. The noise emission for an empty roller coaster vehicle with overriding suspension has been measured to 74 decibels (A) (Menge, 1999). It should be noted here that roller coasters have high speeds and free fall events occurring during a ride which cause higher noise emissions (Menge, 1999). Electric vehicles have lower noise emissions compared to conventional vehicles with internal combustion engines. However, this difference is only noticeably for low speeds (Marbjerg, 2013). With speeds over 50 km/h the noise emission is mainly determined by the tire on the pavement and the noise emissions are almost equal (Bernhard et al., 2005). The noise emission of an electric vehicle with a speed of 50 km/h has been estimated by Marbjerg (2013) to 65 decibels (A) on an asphalt surface. Based on both measurements of roller coasters and electric vehicles no statement about the noise emission of the City Coaster can be taken because there will be no free fall events, only speeds of 50 km/h will be reached and the tires of the City Coaster are not comparable with rubber tires on an asphalt pavement. The noise emissions of the Vectus PRT system in Suncheon were determined to maximum 70 decibels (A) at a speed of 45 km/h (Gustaffson & Lennartsson, 2008). The noise emission of the City Coaster specific should be determined during the development of the system. A price index for noise emissions has been estimated on 27.97 Euro per person per decibels over the lower limit of 60 decibels (A) (Ruijgrok, 2011). The depreciation of house prices can be calculated with a noise sensitivity depreciation index (NSDI) (den Boer et al., 2008) which means that every extra noise level of 1 decibels (A) results in a lower house price. The NSDI is location specific (den Boer et al., 2008) and should therefore be estimated for the Rotterdam case study. This is out of scope of this research and therefore the noise emissions cannot be monetized for the City Coaster. These costs will be estimated pro memorandum.

Nature and visual intrusion

The City Coaster has an impact on park 16Hoven and causes visual intrusion on the northern part of the highway A13 (Figure 4-2). Recreational activities in park 16Hoven can be negatively affected by the City Coaster. The allotments and houses near the City Coaster track are affected by the visual intrusion of the City Coaster. Ruijgrok (2011) states that view of greenery increases the house prices by 5-14%. In other words, if the residences have now a free view to greenery, the house price can decrease up to

14% if a City Coaster affects the free view. Next to that, if the recreational visits of park 16Hoven decreases because of the City Coaster, per unmade visit (because of the unattractiveness of the park) the social cost is estimated on 1 Euro (Ruigrok, 2011). How the City Coaster through park 16Hoven has an impact on the house prices near park 16Hoven is not clear and should be investigated further. The decrease in recreational visits to the area has not been estimated in this research and should also be investigated further. Therefore, these costs will be estimated pro memorandum.

Next to bear the social costs of noise emissions and nature and visual intrusion, it could be chosen to build a tunnel which prevents the noise emissions, nature impact and visual intrusion. According to engineers at Witteveen+Bos, the costs of a small tunnel are approximately 2500 Euro per square meter. A tunnel with a width of 5 meters and a length of 1 kilometer costs then approximately 12.5 million Euro. Whether these investment costs for the tunnel weigh up to the social costs of noise emission, nature and visual intrusion is doubtful. The total investment costs increase by more than fifty percent if it a tunnel must be built.

Discount rates

Because costs and benefits rarely occur equal in time, their value must be recalculated to a common base year (Romijn & Renes, 2013). The recalculation is done with a discount rate, it generates the present value of a policy. The present value has been calculated with:

$$Present\ value = yearly\ costs * \frac{1}{(1+i)^{n-k}}$$

in which i is the interest rate, n is the future year and k is the base year. By estimating the present value of all effects, the balance of costs and benefits of the policy in the base year can be obtained. If this balance is positive the policy is socially profitable, if this balance it is negative, it is not (Romijn & Renes, 2013). The discount rates are established by the Dutch 'Steunpunt Economische Expertise'. For public investments and travel time gains a discount rate of 4.5% has been used. Environmental impacts have a discount rate of 3% (Steunpunt Economische Expertise, 2017).

Final table cost benefit analysis

Table 6-3 shows the outcomes of the CBA for the different scenarios. The City Coaster has a positive cost-benefit ratio in scenario 2.1 to 3.4. Only in scenario 1, in which no modal shift occurs, the cost-benefit ratio is below 1. This means that the benefits for society are smaller than the costs. Most benefits occur for the people traveling to the airport area. The travel time gain lies between 14 and 18 million as the consumer surplus can increase up to 78 million (based on the interview data). For people not using the City Coaster, the costs are higher than the benefits (tax and emissions), not taken into account noise, nature and visual intrusion, this would increase the costs even further. The benefits for people living near the proposed track of the City Coaster are because of that, negative. They don't have a better connectivity with the city or a travel time gain. Because of that, these people could be against the City Coaster, they do not gain from it. If an additional stop in for example park 16Hoven will be built, people living there gain from the City Coaster. To estimate the loss or profit of the City Coaster, a closer look at the business case of the City Coaster is required. This will be done in the next section.

Table 6-3: Cost and benefits in net present value over 30 years (in million euro)

	S1	S2.1	S2.2	S2.3	S2.4	S3.1	S3.2	S3.3	S3.4
Track	-20,0	-20,0	-20,0	-20,0	-20,0	-20,0	-20,0	-20,0	-20,0
Stations	-2,0	-2,0	-2,0	-2,0	-2,0	-2,0	-2,0	-2,0	-2,0
Vehicles	-2,3	-2,3	-2,3	-2,3	-2,3	-2,3	-2,3	-2,3	-2,3
Investment costs total	-24,3	-24,3	-24,3	-24,3	-24,3	-24,3	-24,3	-24,3	-24,3
Maintenance track	-3,3	-3,3	-3,3	-3,3	-3,3	-3,3	-3,3	-3,3	-3,3
Maintenance vehicles	-1,2	-1,2	-1,2	-1,2	-1,2	-1,2	-1,2	-1,2	-1,2
Personnel	-4,8	-4,8	-4,8	-4,8	-4,8	-4,8	-4,8	-4,8	-4,8
Energy	-0,2	-0,4	-0,4	-0,4	-0,5	-0,5	-0,6	-0,7	-0,7
Operational costs total	-9,5	-9,7	-9,7	-9,8	-9,8	-9,9	-9,9	-10,0	-10,0
City Coaster airport pax	10,1	15,3	15,3	19,1	19,1	29,3	29,3	36,6	36,6
City Coaster employees	1,6	8,3	9,5	8,3	9,5	8,3	9,5	8,3	9,5
Less operating benefits Bus 33	-7,3	-7,3	-7,3	-7,3	-7,3	-7,3	-7,3	-7,3	-7,3
Other public transport	0,0	14,6	14,6	18,2	18,2	50,7	50,7	63,4	63,4
Operational benefits total	4,4	30,8	32,1	38,3	39,5	81,0	82,3	101,0	102,2
Travel time gain airport pax	11,8	11,8	11,8	14,8	14,8	11,8	11,8	14,8	14,8
Travel time gain employees	2,1	2,6	2,9	2,6	2,9	2,6	2,9	2,6	2,9
Travel time gain total	13,9	14,4	14,7	17,3	17,7	14,4	14,7	17,3	17,7
Consumer surplus parked	0,0	6,9	6,9	8,7	8,7	24,1	24,1	30,2	30,2
Consumer surplus K&R	0,0	3,7	3,7	4,7	4,7	13,0	13,0	16,3	16,3
Consumer surplus taxi	0,0	7,4	7,4	9,2	9,2	25,8	25,8	32,2	32,2
Consumer surplus total	0,0	18,1	18,1	22,6	22,6	63,0	63,0	78,6	78,6
Government tax parked	0,0	-1,1	-1,1	-1,3	-1,3	-3,7	-3,7	-4,6	-4,6
Government tax K&R	0,0	-0,9	-0,9	-1,1	-1,1	-3,0	-3,0	-3,8	-3,8
Government tax employees	0,0	-2,2	-2,5	-2,2	-2,5	-2,2	-2,5	-2,2	-2,5
Taxes total	0,0	-4,1	-4,4	-4,6	-4,9	-8,9	-9,2	-10,6	-10,9
Emissions bus	0,5	0,5	0,5	0,6	0,6	0,5	0,5	0,6	0,6
Emissions car parked	0,0	0,7	0,7	0,8	0,8	2,3	2,3	2,9	2,9
Emissions K&R	0,0	0,5	0,5	0,7	0,7	1,8	1,8	2,3	2,3
Emissions taxi	0,0	0,1	0,1	0,1	0,1	0,3	0,3	0,4	0,4
Emissions employees	0,0	0,6	0,7	0,6	0,7	0,6	0,7	0,6	0,7
Emissions PT parked	0,0	-0,4	-0,4	-0,5	-0,5	-1,3	-1,3	-1,6	-1,6
Emissions PT K&R	0,0	-0,1	-0,1	-0,2	-0,2	-0,5	-0,5	-0,6	-0,6
Emissions PT taxi	0,0	0,0	0,0	0,0	0,0	-0,1	-0,1	-0,1	-0,1
Emissions PT employees	0,0	-0,3	-0,4	-0,3	-0,4	-0,3	-0,4	-0,3	-0,4
Emissions total	0,5	1,5	1,6	1,8	1,9	3,4	3,5	4,2	4,2
Nature (PM)	-	-	-	-	-	-	-	-	-
Noise (PM)	-	--	--	--	--	---	---	---	---
Visual intrusion (PM)	-	-	-	-	-	-	-	-	-
Total costs	-41,1	-46,3	-46,7	-47,0	-47,4	-52,6	-53,0	-54,8	-55,3
Total benefits	26,1	73,0	74,8	88,3	90,1	171,3	173,0	211,1	212,8
Net present value	-14,9	26,7	28,1	41,4	42,7	118,7	120,0	156,2	157,6
Benefits/costs ratio	0,64	1,58	1,60	1,88	1,90	3,26	3,27	3,85	3,85

Business case

With the yearly costs and yearly operational benefits the subsidies can be calculated.

Yearly costs

The yearly investment costs of the City Coaster can be calculated by calculating the annuity costs of the investment. With the annuity, a series of equal payments for an investment can be calculated (Lindström et al., 2015) assuming that the investment capital is not available and should be lend at a specific interest rate. The annuity formula is attached in Appendix 22. The total yearly investment costs are 1.49 million. Following from the CBA, the yearly operating costs were estimated maximum 0.60 million in scenario 3.4. The operating costs can be seen in Table 6-4. Together with the investment costs the total yearly costs of the City Coaster are 2.05 million to 2.07 million dependent on the scenario.

Yearly operating benefits

The yearly operating benefits of the City Coaster per demand scenario have been estimated in Table 6-3. The investment and operating costs can only be financed by the operating benefits of the City Coaster in scenario 3.1 to scenario 3.4. In these scenarios, the airport passenger modal split of public transport increases to 34.7%. Without this modal shift to 34.7% the City Coaster is unprofitable and subsidies would be required to operate the system.

Subsidies

Based on the yearly investment costs, operating costs and operating benefits the profit or loss can be calculated per scenario. The loss is then the subsidy required to make the system break even. The subsidy per scenario can be seen in Table 6-4. As also can be seen in Table 6-4, the operating costs can be covered by the operating benefits in every scenario. If the government would subsidize the investment costs of the system, the system will be profitable in every scenario.

Table 6-4: Subsidy of the City Coaster (in 1000 Euro)

	S1	S2.1	S2.2	S2.3	S2.4
Yearly investment costs	1490	1490	1490	1490	1490
Yearly operating costs	564	576	578	580	582
Yearly total costs	2054	2066	2068	2070	2072
Yearly operating benefits	679	1,360	1,440	1,580	1,660
Yearly subsidy	1375	706	628	490	412
pax-trips/year [-]	250,000	577,000	620,000	651,000	693,000
Subsidy per pax-trip [€]	5.50	1.22	1.01	0.75	0.59
1000 pax-km	1250	2885	3100	3255	3465
Subsidy €/1000pax-km	1100	244	203	151	119
Infrastructure costs €/1000 pax-km	1192	516	481	458	430

The subsidy depends on the operating benefits of the City Coaster and with that on the number of passengers. If the airport is not allowed to expand and no further office spaces will be build, the system can be self-sufficient if a modal shift to public transport of the passengers of 34.7% and a shift of employees to 18.1% occurs.

Comparison with other public transport modes

CE Delft estimated subsidies of public transport for 2010 (Schroten et al., 2014). It was found that a bus received 619-636 Euro subsidy per 1,000 passenger-kilometer. For tram this was 188 – 205 Euro per 1,000 passenger-kilometer and for metro it was 60-77 Euro per 1000 passenger-kilometer. Comparing this with the City Coaster, the subsidy of the City Coaster is less than it is for a bus in scenario 2. Schroten et al. (2014) also estimated infrastructure costs of public transport systems. As stated in the introduction, the City Coaster seems a lighter system compared to other public transport systems. It was argued in the introduction that because of the light design, the system would also be cheaper. Based on the analysis of CE Delft, the infrastructure costs of a bus system are estimated on 124 Euro per 1000 passenger-kilometer. Tram and metro have infrastructure costs of 81 and 73 Euro per 1000 passenger-kilometer respectively. The infrastructure costs of the City Coaster are estimated on 430 Euro per 1000 passenger-kilometer in scenario 2.4. This high value is mainly determined by the low demand, in case more people use the system, this value decreases. On the other hand, the construction costs of 1 km City Coaster track, two ways, was estimated at Witteveen+Bos at 4 million Euro per kilometer. According to the 'Waaier van Brogt' (Goudappel Coffeng, 2013-b), the investment costs of a simple, 2-way tramline, are 20 million Euro, for a metro (partly under- and above ground) this value has been estimated at 140 million Euro.

Sensitivity analysis

A Sensitivity analysis in cost benefit analyses is performed to investigate the uncertainty of costs and benefits estimated in the CBA. For this cost benefit analysis, the uncertainty of the investment costs, the consumer surplus and the discount rates have been analyzed. All investment costs are increased by 25% (1), the consumer surplus based on the interviews has been neglected (2), no operational benefits from other public transport (3) and the discount rates have been increased to 10%. The cost-benefit ratios in these scenarios can be seen in Table 6-5.

Table 6-5: Sensitivity of benefits-costs-ratio

Case	S1	S2.1	S2.2	S2.3	S2.4	S3.1	S3.2	S3.3	S3.4
Original	0.64	1.58	1.60	1.88	1.90	3.26	3.27	3.85	3.85
+25% investment costs (1)	0.55	1.39	1.42	1.67	1.68	2.92	2.93	3.47	3.47
No consumer surplus (2)	0.64	1.19	1.21	1.40	1.42	2.06	2.08	2.41	2.43
No benefits other PT (3)	0.64	1.26	1.29	1.49	1.52	2.29	2.31	2.69	2.70
(1) + (2)	0.55	1.05	1.07	1.24	1.26	1.85	1.86	2.17	2.19
(2) + (3)	0.64	0.87	0.90	1.01	1.04	1.09	1.12	1.26	1.28
Discount rate of 10%	0.46	1.19	1.21	1.42	1.44	2.53	2.54	3.02	3.03

As can be seen from the table, the consumer surplus and the benefits for other public transport have a major impact on the benefits-costs ratio. A combination of both (2) + (3) makes the benefits-costs ratio below 1.0. In the other cases the ratio remains above one, expect for scenario 1.

6.3 Political feasibility

Social acceptability is according to Feitelson & Salomon (2004) one factor involved in political feasibility, as politicians do take account of voter preferences. However, as politicians do need the support of interest groups, they try to accommodate specific demands of active lobbies, whether they represent industry interests or non-business interests. It can be said that politicians try to maximize the support they receive from interest groups, in a way that is socially acceptable. Moreover, decision makers try to solve the perceived problems, in a way that is social acceptable and that is justified with arguments that are within the present dominant discourse and so that they get more support from interest groups (Feitelson & Salomon, 2004). For this research, the political feasibility will be analyzed by interviewing political decision makers to ask for their opinion about the City Coaster. The political decision makers consulted are city council member Lennart Harpe of Delft (portfolio traffic, transport, land affairs & real estate, waste policy, 'Spoorzone' and Delft Southeast) and provincial executive Floor Vermeulen of South Holland (portfolio traffic and transport, transport authority MRDH, communication and licensing). The following follows from the interviews with the political decision makers.

Currently, there is an increasing demand for on-demand transport which is expected to increase even further in the future. At locations where for example the capacity of conventional public transport is too high, on-demand systems could be used to serve the (low) demand. This can for example be seen in Delft at Delft Zuid where small shuttles bring passengers from the station to a location on the TU Delft campus. The same issue can be seen at Rotterdam – The Hague Airport. The busses ride most of the time empty between Meijersplein and Overschie, only to offer a high frequency to airport passengers. An on-demand system would therefore be advisable. The City Coaster could offer a solution for the issues at Rotterdam – The Hague airport, especially if no subsidy is required if the modal shift occurs as explained in Chapter 5. For the case study, it is according to the decision makers politically not feasible to implement the City Coaster between Rotterdam – The Hague Airport and Central Station. The main reason mentioned by both decision makers is the visual intrusion caused by the City Coaster for the people living close to the City Coaster track. Resistance from these people is expected. It is therefore advised not to build a City Coaster track near or through residential areas or at locations where the City Coaster can have a visual impact as for example nature and parks. On the other hand, if the system requires subsidy (in scenario 1, 2.1, 2.2, 2.3 and 2.4), the societal value of a system to the airport is doubtful, in the case of the airport, the City Coaster does not fulfill a societal need. Airport passengers travelling to the airport pay approximately € 100-200 for their flight. The question rises why the government should subsidize these people if they are able to pay a flight ticket. The public transport budget of the metropole region is limited and investments are therefore scarce. They question why subsidies with public money should be used to offer a better accessibility to the airport for people that are able to pay a flight ticket of 100-200 Euro if there are other projects which are socially more desirable (e.g. connection of residential areas with the public transport network). Lastly, a general resistance against a system to improve the accessibility of Rotterdam – The Hague airport is expected. By improving the accessibility of Rotterdam – The Hague airport, the attractiveness of the airport will increase. People living near the airport expect then to have more nuisance caused by the airport and will therefore be against a system improving the accessibility of the airport. By having more public resistance the political feasibility will decrease.

The political decision makers are however divided regarding the City Coaster in general. Mr. Harpe expects that in the future autonomous vehicles on street level will be able to transport people from A to B and thinks that the City Coaster is therefore not future proof. The costs of the City Coaster are mainly determined by the infrastructure costs. Even if the benefits can bear the costs in the business case and no subsidy would be required, an investment is still needed which will be amortized over thirty years. When looking at the current technologies developed, it is uncertain whether a system as the City Coaster is still required in the future (15 to 20 years) according to Mr. Harpe. Mr. Vermeulen acknowledges that innovations are needed in the current (public) transport market. Waiting for an innovation that in the end maybe will never be feasible is according to Mr. Vermeulen not the right approach. If a current innovation is able to solve the current problems it should be taken into consideration, including the City Coaster. However, the visual intrusion, as mentioned before, and the integration of the City Coaster in the current infrastructure should then be dealt with first.

7 Usefulness of the model of Feitelson & Salomon

As mentioned in the introduction, the usefulness of the model of Feitelson & Salomon (2004) will be discussed based on a reflection on the feasibility analysis of the City Coaster. The results of this analysis have been presented to decision makers in the field to assess the information provided by the model.

7.1 Reflection based on the feasibility analysis of the City Coaster

Applying the model of Feitelson & Salomon gave insights in the usefulness of the model. Holding strictly on to the model showed that the model has two limitations. The stakeholder analysis showed that the stakeholders were most interested in the business case and the technical feasibility of the City Coaster. The social acceptance and political feasibility was for the stakeholders of minor concern. By using the model as a practical tool for the case study it was found that the model does not take into account the current applicable legislation and regulation to which the transport innovation must comply. One can argue that this is part of the technical requirements, however, this is not explicitly mentioned by Feitelson & Salomon (2004). Next to that, the model describes the distribution of benefits and costs. According to Feitelson & Salomon (2004) an innovation is not likely to be seen as feasible unless it can also pass a benefit-cost criterion. The cost benefit analysis of the City Coaster showed, that the benefits exceed the costs in every scenario except scenario 1 in which no modal shift occurs. According to the model, it is then economically feasible if it exceeds the benefit-cost criterion. However, in scenario 2.1, 2.2, 2.3 and 2.4 the yearly operational benefits do not exceed the investment and operating costs. In these scenarios, operation of the City Coaster requires subsidies. Based on the consultation of the decision makers, information regarding the subsidies is important to make a decent decision. Passing a benefit-cost criterion is therefore not sufficient to be economically feasible. The business case gives additional insights to the decision makers.

For the case study, it was found that the City Coaster is politically not feasible. If this would have been known first, the technical, economic and social feasibility would not have been necessary to analyze. Based on the case study it can be concluded that the political feasibility was most significant.

7.2 Decision makers in the field

The outcomes of the feasibility study of the City Coaster have been presented to the two decision makers as mentioned in section 6.3. The following follows from the interviews with the political decision makers.

Based on the conversations with the decision makers it has been found that the model does indeed provide useful information to the decision makers. In general, decision makers need to know the following to make a decent decision regarding the adoption of a transport policy (in random order):

- What problems are solved with the policy
- What will be improved with the policy
- Investment costs
- Benefits
- Transport volume

- What other investments have to be skipped to implement the policy (budget)
- Impact on society and environment (e.g. noise, safety)
- Social acceptance
- Technical feasibility

As can be seen from this list, most of the items (except 'what other investments have to be skipped to implement the policy') can be covered with the political economy model of Feitelson & Salomon (2004).

According to the decision makers, the first requisite for adoption that must be considered is the technical feasibility. The innovation must be technically feasible before other requisites are analyzed. Based on experience several innovations have been discussed which in the end were not technically feasible. This unnecessary cost a lot of time. Then, the social feasibility should be investigated because this affects the opinion of the decision makers. A cost-benefit analysis should be conducted in which the effectiveness of the policy (who will benefit from it) but also the environmental impact should be taken into account. The economic feasibility plays an ever-increasing role since the transportation budgets gradually decrease. According to the decision makers the political feasibility depends on the technical and social feasibility. This requisite for adoption should be considered in the end. However, the political feasibility is hard to predict. The factors identified by Feitelson & Salomon (2004) affect indeed the political feasibility, but according to the decision makers there will probably more factors affecting it. For example, if politicians want to leave a remarkable policy behind for their city, it is hard to estimate it based on a model. The decision-making procedures are according to the model (as can be seen in Figure 6-1) a factor affecting political feasibility. The decision-making procedures play according to the decision makers a significant role in the political feasibility of a transport policy. In general, it can be seen that these decision-making procedures delay the process to make a decision. With infrastructure policies, in the starting phase most stakeholders are enthusiastic about the idea. Then, an environmental impact assessment and cost-benefit analysis for different designs has to be conducted according to the decision-making procedures. People negatively affected start to resist against the policy which will increase once a final design has been chosen. These people have mostly a 'not in my backyard' attitude. If elections take place during the development of a policy, history showed that the politicians will be restrained in making major decisions. Next to that, elections induce a change of power, a new decision-maker can have another opinion than his predecessor. The transmission of knowledge regarding the policy is minor which slows down the total process. In the end, the policy can be implemented albeit with a delay. However, for transport innovations, this delay can be critical because of the fast changing technology.

8 Conclusion and discussion

The objective of this research was to analyze the feasibility of the City Coaster based on the model of Feitelson & Salomon (2004) and to evaluate the usefulness of the theoretical model of Feitelson & Salomon for real world applications.

The research questions of this research were:

"Under which conditions is the City Coaster feasible?"

and

''To what extend is applying the model of Feitelson & Salomon useful in the decision-making process of transport innovations such as the City Coaster?"

To answer these research questions a case study to the City Coaster has been conducted, the design of the case study has been analyzed according to the political economy model of Feitelson & Salomon (2004) and this model has been assessed by decision makers in the field.

The model of Feitelson & Salomon describes that a transport innovation can only be adopted if the innovation is technical, social and political feasible. Based on the results of this report it has been found that the City Coaster is technically feasible. The technical feasibility has been analyzed based on expert judgement from experts from the roller coaster and automotive industry. Based on their judgement the City Coaster is technically feasible by using intelligent vehicles on dumb infrastructure.

The interviews with airport passengers showed a positive attitude from the passengers towards the City Coaster. Only 4% of the respondents would not use a City Coaster because of a dislike towards the system (afraid of heights, no driver, high speed, shared vehicle). Compared to bus, tram, metro and train, the City Coaster was preferred above the other transport modes. Younger people tend to use the City Coaster more than elder people, the same holds for business people compared to leisure travelers. People traveling with their partner would use the City Coaster less compared to someone traveling alone. Next to that, people traveling with friends or colleagues have a higher preference for the City Coaster compared to people traveling alone.

Based on the cost-benefit analysis it was found that in every scenario the benefits are greater than the costs, except for scenario 1 in which no modal shift nor growth occurs. In these cost-benefit analyses noise, nature and visual intrusion have not been monetized, these costs will have a negative impact on the cost-benefit ratio. Next to the cost-benefit analysis, the business case of every scenario has been discussed. It was found that subsidies are required if the modal shift of airport passengers will not be 34.7%.

The political feasibility has been analyzed based on interviews with two decision makers. The visual intrusion of a track on a height of five meters above ground level will induce, according to the decision makers, resistance from residents living near the track. Next to that, they question the societal value of the system if subsidies would be required. If the airport passengers are able to buy a flight ticket, then they can also pay for their transportation to the airport. Lastly, a general resistance against a system to improve the accessibility of Rotterdam The Hague airport is expected because the attractiveness of the airport will increase. People living near the airport expect then to have more nuisance caused by the airport and will therefore be against a system improving the accessibility of the airport. In general, the decision makers are divided regarding the City Coaster. On the one hand, it is expected that the City Coaster is not future proof if automated vehicles are able to drive on public roads. On the other hand, by waiting for an innovation that maybe never will occur will not solve the current problems in the (public) transport sector.

It can be concluded that, based on the analysis, the City Coaster between Central Station and Rotterdam – The Hague airport is not feasible. It is a technical feasible system which can be cheaper than conventional public transport systems and is accepted by people who will use the system. However, the visual intrusion of the City Coaster makes the City Coaster politically not feasible. Other infrastructure projects such as the RijnGouwelijn in Leiden and the RegioTram in Groningen are examples which also failed because of the visual intrusion and resistance from inhabitants. To solve the visual intrusion and impact on nature for the Rotterdam case study, the City Coaster can be built underground. As mentioned in section 6.2.4, the investment costs of 1 km small tunnel for the City Coaster, are approximately 12.5 million. These additional investments have a negative impact on the cost benefit ratio, however it remains greater than 1.0 in every scenario except scenario 1. The visual intrusion and nature issues can therefore be solved with a tunnel. However, the arguments that a City Coaster has low societal value and the general resistance against a system improving the accessibility of the airport still remain. The City Coaster for the Rotterdam case study remains therefore unfeasible.

Generally speaking, the City Coaster is feasible under the conditions that the visual intrusion has to be eliminated by building the City Coaster underground, within buildings or shielded from public space. If subsidies are required, it should fulfill a societal need. Based on the feasibility analysis to the Rotterdam case study it has been found that the City Coaster is economically feasible in almost all demand scenarios. These scenarios could fit at many other locations, another location where the City Coaster has high potential to be feasible is for example Schiphol airport. It could offer transport services between the current terminal and the future planned remote terminal. The visual intrusion around Schiphol will be insignificant which makes it more feasible. Next to that, the system will be (semi) privately owned in this situation which induces no public investment. The analysis to comparable systems in Chapter 2 showed that privately owned systems have more potential to succeed. A connection that was mentioned by the stakeholders of the case study was metro station Meijersplein and the airport terminal. The advantage of this connection is that the visual intrusion is limited and the track can be built on street level. Therefore, the cost-benefit analysis for this connection has been analyzed. For this analysis, it is assumed that no additional travelers will use the system because the travel time will not reduce as much as it does with a connection to central station, people still have to travel to Meijersplein and transfer to the City Coaster. The cost benefit ratio for Meijersplein is 0.51 which shows that the City Coaster is economically not feasible for this connection. The demand is too low.

According to one decision maker, the City Coaster is not future proof because it requires an infrastructure which will be needless if automated vehicles can operate on the public road in the future. How long it will take until these automated vehicles are able to operate in the city is not clear. Currently, an automated vehicle is not able to operate in the city because it will participate safely on every incentive caused by other road users, an automated vehicle will therefore not be able to move forward in the city (C. van de Weijer, personal communication, May 15, 2017). Assuming that this issue can be solved and automated vehicles can be used in cities, it should be asked how they then will be used in the cities. Three inner city applications of automated vehicles are identified: private automated vehicles, automated shared vehicles as last mile solution and automated shared vehicles for door to door travel (KiM, 2017). If automated vehicles are used privately, the congestion is expected to increase, especially in inner cities (KiM, 2017; Glus et al., 2017). If automated vehicles are used as last mile solution, it is expected that conventional public transport systems transport people to the city and the automated vehicles are used as last mile solution on dedicated trajectories (KiM, 2017). For the latter one, it is expected that congestion decreases because vehicle sharing increases (KiM, 2017). However, these are expectations, the development of automated vehicles is currently underway. Next to that, it depends on the vision of the region or the city in which the automated vehicles will operate. They should ask themselves how these automated vehicles should operate in their city. Are they operating in mixed traffic, or do they have a dedicated infrastructure? Do they want these vehicles in the inner city, or should they be parked on the edges from where the passengers take a shared vehicle or a bike or conventional public transport to the inner city? These questions should be answered first by the cities, then it can be investigated how and if the City Coaster can be part of this. Just like the automated shared vehicles, the City Coaster can be used as last mile solution with currently available technology, especially if the visual intrusion can be deducted.

Regarding the model of Feitelson & Salomon it can be concluded that the model provides useful information to decision makers. Based on the interviews with the decision makers it has been found that required information by the decision makers is covered by the model. The technical feasibility is according to the decision makers most important and the political feasibility is according to them hard to estimate. The factors identified by Feitelson & Salomon do indeed play a role in the political feasibility, however, there are probably more unidentified factors affecting the political feasibility which could not be identified by the decision makers. With the outcomes of the model of Feitelson & Salomon, the decision makers are able to make a decent decision regarding future transport innovations.

9 Limitations and recommendations

In this part, it will be reflected on the research methodology used to come to the conclusions as stated in Chapter 8. After discussing the limitations recommendations will be given. For clarification, the research structure as mentioned in the introduction can be seen in Figure 9-1.

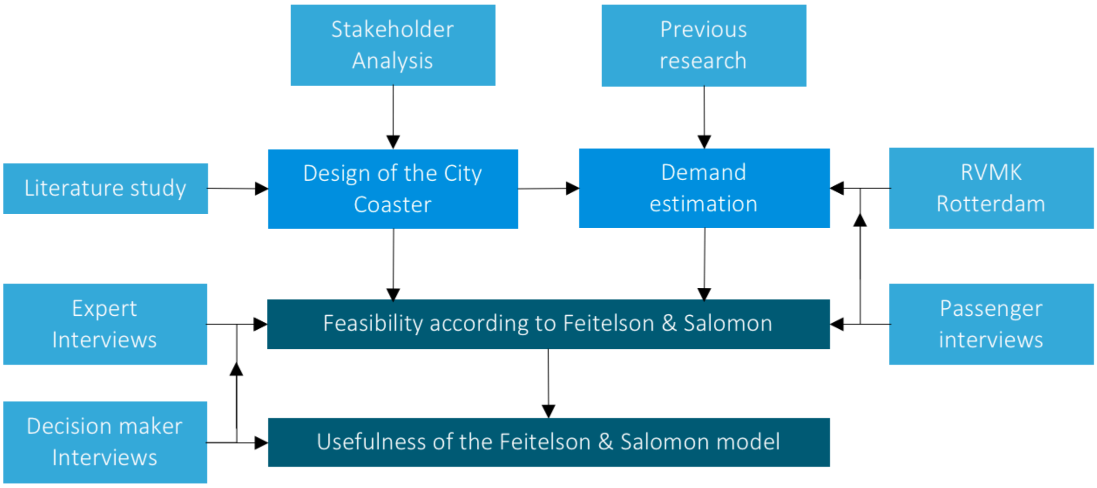


Figure 9-1: Research structure

For the design of the City Coaster it was tried to get in contact with a Dutch PRT company, 2Getthere. Unfortunately, they were not willing to cooperate because of competitive reasons. Therefore, an assumption had to be made regarding the vehicle weight of the City Coaster. To estimate the vehicle fleet of the City Coaster, the simulation software PRTsim would be used. However, this software was not able to read the demand file of this case study. The number of vehicles has been estimated therefore analytically in Microsoft office Excel. The distribution of the on-demand vehicles is therefore assumed to be static which means that the vehicles ride with a specific frequency.

The demand estimation is based on airport data, OV-Chipcard data, the transport model of Rotterdam and the interviews with airport passengers. According to the airport data, the public transport modal split is currently 12% (535 trips). According to the OV-Chipcard data, 610 trips are made per day to and from the airport by public transport. Then, there are 75 trips left for employees. Taking into account other bus stops as well, a public transport modal split of employees can be estimated to 4.2%. This is not in line with the outcomes of the transport model of Rotterdam. Therefore, the airport region as a whole had to be considered in the model. Next to that, the origins and destinations of airport passengers are all located within the region Rotterdam The Hague according to the model. This is not in line with the data according to brands et al. (2015). It was therefore advised to only estimate a modal shift to the City Coaster with the model. This limited the research because other information (e.g. origin/destination, travel time) would be required further on in the research for the cost-benefit analysis. Next to that, the model does not distinguish between public transport modes, all modes are considered public transport and no alternative specific constants are considered. Based on these limitations, it can be concluded that the transport model of Rotterdam was not suitable to model City

Coaster passengers to the airport area. On the other hand, it was the best available option for this research. Because the use of the transport model was limited, it was chosen to conduct interviews at Rotterdam – The Hague airport. A modal shift to the City Coaster is estimated based on the interview data. According to the interviews, the modal split would increase to 46.9%. Amsterdam Schiphol Airport, with a perfect train accessibility, has currently a public transport modal split of 42% (Royal Schiphol Group, 2017). With the City Coaster, an additional transfer at Central Station to the City Coaster would still be required, the estimated share seems therefore not realistic. A social desirability bias had to be assumed of 35% based on a marketing research. The modal shift to public transport would then be 34.7%. Information regarding employees has not be obtained because of the unwillingness of the companies to cooperate and the non-interest of employees to fill in a short online survey.

For the cost benefit analysis in the feasibility study, the costs of the City Coaster had to be estimated. The infrastructure costs were estimated at Witteveen+Bos. The investment costs of the stations and the vehicles were estimated based on benchmarking with other public transport stations and automated/electric vehicles respectively. This made these costs estimations less reliable. Next to that, it was assumed that one maintenance employee would be required. The operating benefits and the external costs/benefits were estimated based on the interview data. This data was conducted from 38, 32 and 10 observations for Kiss & Ride, car parked and taxi users respectively (only observations of interviewees who would use the City Coaster were used). Based on these observations, average numbers for these passengers are conducted. If a transport model was used, this could be estimated for every traveler individually which would make it more reliable than using average numbers. The same holds for the consumer surplus calculation. Also for the employees no data was available. Therefore, the consumer surplus of employees was not taken into account and for the external costs an average distance of 22 kilometers was assumed according to Kalter et al. (2010).

The political feasibility has been assessed by decision makers in the field. The City Coaster was introduced to the decision makers and the image as shown on the front page of this report was shown for clarification. This picture shows the City Coaster on height which could have biased the decision makers. The City Coaster can also be implemented on street level or in a tunnel. This was not explicitly mentioned to the decision makers. Next to that, the case study is about Rotterdam The Hague Airport. If the case would have been the accessibility of the City of Rotterdam by building a transferium near the A13/A16 from where passengers can be transported with the City Coaster to the city center (and with that passengers of the airport, as side effect), the political feasibility could have been different.

The abovementioned reflection shows assumptions made by the author. It was desired to use as reliable data as possible. However, this data is not always available and one had to work with the most reliable data available at disposal.

For the case study the following recommendations can be given. The demand estimation should be done with a stated choice experiment under airport passengers and employees of the area. The model used to estimate the modal shift is not designed for airport passengers and gives therefore only a rough estimation for the modal split.

Recommendations for Witteveen+Bos regarding the City Coaster can be given. For the design of the City Coaster assumptions were made regarding the City Coaster. It is recommended to conduct further research to the design of the City Coaster track because the track determines mainly the investment costs of the system. The track should not only have low investment costs, also the visual intrusion of the track should be limited. As followed from the political feasibility, it is not advised to build an elevated City Coaster track because the resistance of people affected by it will induce no political support. It should be investigated how a City Coaster can be implemented in the City without causing visual intrusion. If no elevated track is required, it should be questioned why the vehicles should ride on a rail system. Looking at the current automated vehicle technology, it can be expected that automated vehicles can achieve the same speed as the City Coaster on for example a concrete or asphalt pavement. As mentioned in this report, viable information regarding the vehicles was hard to obtain because of competitive reasons. Research should therefore be conducted to the design of the vehicles. By using light-weight vehicles, the construction can be lighter which will safe investment costs. Finally, the automation of the system using vehicle to vehicle technology should be investigated. A control system needs to be designed which describes the operation of the City Coaster.

For future transport innovations, the model of Feitelson & Salomon (2004) is a useful tool to evaluate its feasibility. Based on the case study and according to the decision makers it has been found that the model provides useful information for the decision makers. Most information required by decision makers to make a decent decision is covered in the model. Which requisite for adoption must be investigated first, depends on the situation. If a transport innovation is a solution for a dedicated case, it is advised, based on the case study to the City Coaster, to analyze the political feasibility first. For a more general research to a transport innovation, it is advised by the decision makers to analyze the technical and social feasibility first before investigating the political feasibility. If subsidies are required it is advised to analyze the business case next to the cost benefit analysis. These conclusions follow from only one case study. It is therefore recommended to confirm or disintegrate the importance of the requisites for more cases. Lastly, the case study showed that a non-monetizable cost (visual intrusion) was the show stopper for the political feasibility of the City Coaster. These non-monetizable costs are not explicitly mentioned by Feitelson & Salomon. The interaction between these costs and the political feasibility should be investigated further because there is no direct connection between the cost benefit analysis and the political feasibility in the model of Feitelson & Salomon (2004).

10 References

9292 (2017). *Public transport options to and from RTH-Airport on Friday March 31, 2017.* Retrieved February 27, 2017 from: http://9292.nl/reisadvies/station-delft/rotterdam_luchthaven-rotterdam-the-hague-airport/vertrek/2017-03-31T0858?via=station-rotterdam-centraal&metro=off

Adell, E., Nilsson, L. & Várhelyi, A (2014). 'How is Acceptance Measured? Overview of Measurement Issues, Methods and Tools'. In Regan, A., *Driver Acceptance of New Technology: Theory, Measurement and Optimization* (pp 73-88). Boca Raton, United States of America: CRC Press

Agirre, X. & Abad, G. (2016). 'Railway traction'. In Abad, G., *Power electronics and electric drives for traction applications*. First edition. John Wiley & Sons, Ltd.

AHN (2017). *Over AHN.* Retrieved May 17, 2017 from: http://www.ahn.nl/common-nlm/over-ahn.html

Algemeen Dagblad (2016). Poll: Rollercoaster meest populair. Retrieved June 19, 2017 from: http://www.ad.nl/binnenland/poll-rollercoaster-meest-populair~ad3e8918/

Ampt, E., Meyburg, A. & Richardson, A. (1995). 'Sample Size Calculations'. In: Ampt, E., Meyburg, A. & Richardson, A., *Survey Methods for Transport Planning* (pp 101-146). Oakland: Eucalyptus press

Anderson, J. (2016), *Contributions to de development of Personal Rapid Transit Volume 1*. Retrieved from: http://www.advancedtransit.org/wp-content/uploads/2016/02/Anderson-JE-Contributions-to-the-Development-of-PRT-I.pdf

van Arem, B., Chen, Y., Li, H., Li, J. & van Zuylen, H. (2010). 'Demand modeling of innovative transport system PRT at the Rotterdam Port Area'. In *Intelligent Transportation Systems (ITSC), 2010 13th International IEEE Conference on* (pp. 137-142). IEEE.

ARUP (2017), *Heathrow Personal Rapid Transit system*. Retrieved April 20, 2017, from: http://www.arup.com/projects/heathrow_personal_rapid_transit_prt

American Society of Civil Engineers (ASCE) (2014). 'Automated People Mover Standards' Ebook

Bakker, P. & Zwaneveld, P. (2009), 'Het belang van openbaar vervoer, de maatschappelijke effecten op een rij'. Centraal Planbureau & Kennisinstituut voor Mobiliteitsbeleid.

Bates, J., Duijnisveld, M., Haaijer, R., Jansen, B., Meurs, H., Nes van, R., Schie van, C., Snelder, M., Tavasszy, L. & Verroen, E. (2012), *Audit LMS en NRM Syntheserapport*. Retrieved from https://staticresources.rijkswaterstaat.nl/binaries/TNO-rapport%20Audit%20LMS%20en%20NRM%20Syntheserapport_tcm174-356326_tcm21-13482.pdf

Bendixon, T. (1972). 'Cabinentaxi: a personal public transport system'. In *Transportation Journal Vol. 1 no. 3* (November 1972) Amsterdam: Elsevier Publishing Company

Bernhard, R., Wayson, R. , Haddock, J., Neithalath, N., El-Aassar, A., Olek, J., Pellinen, T. & Weiss, W. (2005). An introduction to tire/pavement noise of asphalt pavement. *Institute of Safe, Quiet and Durable Highways, Purdue University*.

Besluit aanwijzing lokale spoorwegen (2013, November 25). Retrieved May 23, 2017, from: http://wetten.overheid.nl/BWBR0034361/2017-04-03

Bly, P. (2011-a). 'Evaluation of passenger satisfaction with the Heathrow PRT System'. Part of the Citymobil project, sixth framework programme, Thematic priority 1.6

Bly, P. (2011-b). 'Comparison of the ULTra PRT system with the existing bus service from the passenger and operator viewpoints'. CityMobil *Deliverable D1*, *2*(3).

Bok de, M. (2015). Guest Lecturer at TU Delft. Lecture for the course CIE 4801, Transportation and Spatial modelling, at October 6 2015: The Dutch National Model system (LMS): methodology.

Brands, T., Bunschoten, T. & Ubbels, B. (2015). 'Rotterdam The Hague Airport. Onderzoek naar vervoersstromen'. Goudappel Coffeng & SEO Economisch Onderzoek

Buehler, M., Iagnemma K. & Singh, S., eds. (2010). *The DARPA Urban Challenge: Autonomous Vehicles in City Traffic*. In Springer Tracts in Advanced Robotics series, Vol. 56, 2010.

Boer den, E., Vreede van de, G., Jong de, F. & Bruyn de, S. (2008). Beleving en MKBA in het geluidsbeleid. Een verkenning naar beleving en kosten-batenanalyse bij de aanpak van geluidshinder. CE Delft.

Carnegie, J. & Hoffman, P. (2007). 'Viability of Personal Rapid Transit In New Jersey'. (No. NJ-2007-001)

Chang, R. (2016). 'Parity: An Intuitive Case'. In Luke Elson (2016), *Ratio, an international journal of analytic philosophy*. *Special Issue: Interdeterminancy in Ethics (pp. 395-411).* New York: Wiley & Sons

Choi, K. (2015). *SunCheon PRT: SkyCube, Project Overview & Operation Status*. Retrieved from: http://www.advancedtransit.org/wp-content/uploads/2015/12/Suncheon-PRT-edited_Podcar-City-9th.pdf

Cook, C., Fereday, D., Lowson, M. & Teychenné, R. (2004). 'Passenger response to a PRT system'. *Transportation Research Board Paper*, 04-3058.

Correia, G., Milakis, D., van Arem, B. & Hoogendoorn, R. (2016). 'Vehicle automation and transport system performance'. In: Bliemer, M., Mulley, C. & Moutou C.: *Handbook on Transport and Urban Planning in the Developed World* (pp 498 – 516). USA, Northampton: Edward Elgar Publishing

CROW (2015). *Achtergronden Organisatie en Spelregels: Financiering openbaar vervoer.* Retrieved February 28, 2017 from: https://www.crow.nl/vakgebieden/verkeer-en-vervoer/bibliotheek/kennisdocumenten/achtergronden-organisatie-ampamp-spelregels-financ

Daniels, P. & Warnes, A. (1980). 'Some topical issues in urban transport decision making'. In Daniels, P. & Warnes, A., *Movement in Cities: Spatial Perspectives on Urban Transport and Travel* (pp 306-348). Oxon: Routledge.

Derksen, R., Kandel, H., Korving, W. & Karrenbeld, B. (2014). *Verkennende studie naar de OV-bereikbaarheid van Rotterdam The Hague Airport.* Rebel Group

Donnea, F.X. (1971), 'Consumer behavior, transport mode choice and value of time: some microeconomic models'. In *Regional and urban economics*, Vol. 1 No. 4 (1972) (pp. 355-382).

Dym, C., Little, P. & Orwin, E. (2004). 'The design process'. In Dym, C., Little, P. & Orwin, E., *Engineering design: a project-based introduction*. Fourth Edition. United Kingdom, West Sussex: John Wiley & Sons Ltd.

Englund, C., Chen, L., Ploeg, J., Semsar-Kazerooni, E., Voronov, A., Hoai Hong, B. & Didoff, J. (2016). 'The grand cooperative drinving challenge 2016: Boosting the introduction of cooperative automated vehicles' In *IEEE Wireless Communications Vol. 23 issue 4 (pp 146-152)*, august 2016

Essen van, H., Davidson, M. & Brouwer, F. (2008). Berekening van externe kosten van emissies voor verschillende voertuigen. Op basis van nieuwe emissiecijfers en met analyse van toekomstige waarderingen. CE Delft.

Eurostat (2017) *Half-yearly electricity prices (EUR).* Retrieved June 2, 2017 from: http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Half-yearly_electricity_prices_(EUR).png

Feitelson, E. & Salomon, I. (2004). 'The Political Economy of Transport Innovations'. In Beuthe, M., Himanen, V., Reggiani, A. & Zamparini, L., *Transport Developments and Innovations in an Evolving World* (pp 11-26). Berlin, Germany: Springer-Verlag

Field, A. (2009). 'Categorical Data'. In Field, A., *Discovering statistics using SPSS (and sex and drugs and rock 'n' roll)* (pp. 686 – 724). Third edition. London: SAGE Publications Ltd

Fisher, R. (1993). 'Social Desirability Bias and the Validity of indirect Questioning'. In *Journal of consumer research, 20(2)* (pp 303-315).

FNV (2017), *Openbaar vervoer CAO.* Retrieved from: https://www.fnv.nl/sector-en-cao/alle-sectoren/streekvervoer/cao-streekvervoer/openbaar_vervoer/

Geels, F.W. (2002). 'Technological transitions as evolutionary reconfiguration processes: a multilevel perspective and a case-study', *Research Policy*, 31(8), (pp 1257–1274).

Gemeente Rotterdam (2017). *Stadsvisie*. Retrieved April 21, 2017 from: https://www.rotterdam.nl/wonen-leven/stadsvisie/

Glus, P., Rothman, E., Iacobucci, J. (2017). Driverless Future: A Policy Roadmap for City Leaders.

Goudappel Coffeng (2013-a). *Verkeersmodel RVMK 3. Actualisering RVMK naar basisjaar 2010*, December 20, 2013. Goudappel Coffeng

Goudappel Coffeng (2013-b). *Waaier van Brogt*, January 16, 2013. Goudappel Coffeng

Graaf de, M. (2011), 'PRT Vehicle Architecture and Control in Masdar City'. In Leder, W. & Sproule, W. (2011), *Automated people movers and transit systems 2011: From People Movers to fully automated urban mass transit* (pp 339-348).

Groot, M. (2004). Milieuprofiel van stroomaanbod in Nederland. CE Delft.

Gustaffson, J. & Lennartsson, S. (2008) Vectus PRT concept and test track experience. Vectus Ltd., Uppsala, Sweden.

Hammersley, M. & Gomm, R. (2008). 'Assessing the radical critique of interviews'. In Hammersley, M., *Questioning Qualitative Inquiry*: *Critical Essays* (pp. 89-100). London: SAGE Publications Ltd

Hoefsloot, N. & Pater de, M. (2011). Indirecte effecten. Een verkenning naar indirecte effecten in Maatschappelijke Kosten-baten- analyses. Decisio

Irving, J., Bernstein, H., Olson, C. & Buyan, J. (1978). 'Network Configurations'. In Irving, J., Bernstein, H., Olson, C. & Buyan, J., *Fundamentals of Personal Rapid Transit*. D.C. Heath and Company

Israel, G. (1992). 'Determining Sample Size'. University of Florida Cooperative Extension Service. Institute of Food and Agriculture Sciences, EDIS.

Kalter, M.J., Bakker, P. & Jorritsma, P. (2010), 'Woon-werkverkeer als drijvende kracht achter groei automobiliteit. Op zoek naar verklaringen voor individuele verschillen in woon- werkafstand autoverkeer'. In *Bijdrage aan het Colloquium Vervoersplanologisch Speurwerk 25 en 26 november 2010, Roermond.*

Khammas, A. (2017), *Buch der Synergie Teil C, Andere elektrische Fahrzeuge, Podcars und People mover*. Retrieved April 19, 2017 from: http://www.buch-der-synergie.de/c_neu_html/c_11_12_neu_mobile_prt_16_podcars.htm

KiM (2013), De maatschappelijke waarde van kortere en betrouwbaardere reistijden. Retrieved from: https://www.rwseconomie.nl/kengetallen/documenten/rapporten/2016/augustus/augustus/de-maatschappelijke-waarde-van-reistijd-en--betrouwbaarheid

KiM (2017), Paden naar een zelfrijdende toekomst, vijf transitiestappen in beeld. Retrieved from: https://www.kimnet.nl/publicaties/rapporten/2017/03/27/paden-naar-een-zelfrijdende-toekomst

King, M. & Bruner, G. (2000). 'Social desirability bias: a neglected aspect of validity testing'. In *Psychology and Marketing*, 17(2) (pp 79–103).

Van der Laan, J.D. Heino, A. & De Waard, D. (1997). 'A simple procedure for the assessment of acceptance of advanced transport telematics'. In *Transportation Research Part C*, 5(1) (pp. 1-10).

Landau, S., Weisbrod, G., Gosling, G., Williges, C., Pumphrey, M. & Fowler, M. (2015). 'Passenger Value of Time, Benefit-Cost Analysis, and Airport Capital Investment Decisions'. In *Volume 1: Guidebook for Valuing User Time Savings in Airport Capital Investment Decision Analysis* (No. ACRP 03-19).

Latour, B. (1996). 'Aramis or the love of technology'. Harvard University Press.

Lawson, J. (2014). 'My pod'. In *Future airport 2014* (1), (pp 59-61). Retrieved from: http://viewer.zmags.com/publication/b0ecc6ab#/b0ecc6ab/58

Lindström, E., Madsen, H. & Nielsen, J.N. (2015). 'Fundamentals'. In *Statistics for finance* (pp. 17-36). CRC Press

Lowson, M. (1999). 'Systems analysis of Personal Transport'. In *INCOSE International Symposium v9 n1* (pp 965-972)

Ludema, M. (2015). Assistant professor TU Delft. Lecture for the course TIL4030 at November 13 2015: *Systems Engineering Processes.*

Manzetti, S., & Mariasiu, F. (2015). 'Electric vehicle battery technologies: From present state to future systems'. In *Renewable and Sustainable Energy Reviews*, *51*, 1004-1012.

Marbjerg, G. (2013). Noise from electric vehicles–a literature survey. *COMPETT Program*.

McKinsey (2017). *Electrifying insights: How automakers can drive electrified vehicle sales and profitability.* Retrieved from https://www.mckinsey.de/files/161223_mckinsey_e-vehicles.pdf

Menge, C. (1999). Noise from amusement park attractions: Sound level data and abatement strategies. *Noise Control Engineering Journal*, *47*(5), 166-168.

Metropoolregio Rotterdam Den Haag (2016). *Lijnnetkaart Openbaar Vervoer Omgeving Rotterdam 2017.* RET

Metropoolregio Rotterdam Den Haag (MRDH) (2017), *Over MRDH*. Retrieved March 29, 2017 from http://mrdh.nl/over-mrdh

Meywerk, M. (2015). 'Driving Resistances, Power Requirement'. In Meywerk, M., *Vehicle Dynamics* (pp 27-41). Wiley & Sons Ltd.

Ministerie van Infrastructuur & Milieu (2012). 'KBA bij MIRT-Verkenningen'. Retreived from: https://www.rwseconomie.nl/documenten/rapporten/2016/augustus/augustus/kader-kba-bij-mirt-verkenningen

Ministerie van Infrastructuur en Milieu (2016). *Overstappen naar 2040. Flexibel en slim OV*

Mueller, K. & Sgouridis, S (2011). 'Simulation-based analysis of personal rapid transit systems: service and energy performance assessment of the Masdar City PRT case'. In *Journal of advanced transportation Vol 45, issue 4* (pp 252-270). John Wiley & Sons Ltd

Mott MacDonald (2017). Audit BOV-kosten lokaalspoor vervoerregio's. Beheer-, Onderhouds- en Vervangingskosten in Amsterdam, Rotterdam en Den Haag. *Metropool Regio Rotterdam Den Haag*

NIBUD (2017). *Wat kost een auto*. Retrieved June 20, 2017 from: https://www.nibud.nl/consumenten/wat-kost-een-auto/

Oeser, M. (2012). Professor at RWTH Aachen University. Lecture for the course Planungsmethodik at November 23, 2012: *Fahrdynamik und Richtlinien*.

Ortúzar, J. & Willumsen L. (2011-a). 'Discrete Choice models'. In Ortúzar, J. & Willumsen, L., *Modelling Transport* (pp 227-268). Fourth edition. United Kingdom, West Sussex: John Wiley & Sons Ltd.

Ortúzar, J. & Willumsen L. (2011-b). 'Data and Space'. In Ortúzar, J. & Willumsen, L., *Modelling Transport* (pp 55-137). Fourth edition. United Kingdom, West Sussex: John Wiley & Sons Ltd.

Ortúzar, J. & Willumsen L. (2011-c). 'Assignment'. In Ortúzar, J. & Willumsen, L., *Modelling Transport* (pp 349-390). Fourth edition. United Kingdom, West Sussex: John Wiley & Sons Ltd.

Ortúzar, J. & Willumsen L. (2011-d). 'Pricing and Revenue'. In Ortúzar, J. & Willumsen, L., *Modelling Transport* (pp 533-549). Fourth edition. United Kingdom, West Sussex: John Wiley & Sons Ltd.

Pemberton, M. (2012). 'The Track to Suncheon: Making APMs intelligent'.In 'Automated people mover transit systems 2013' (pp 263-275).

ProRail (2015), *Ontwerpvoorschrift Kunstwerken – deel 2 – Bouwwerken over en naast het spoor*

PRT Consulting (2010), *Why has Masdar Personal Rapid Transit (PRT) been scaled back?* Retrieved March 22, 2017 from: *http://www.prtconsulting.com/blog/index.php/2010/10/16/why-has-masdar-personal-rapid-transit-prt-been-scaled-back/*

PRT Consulting (2015), *Galleries*. Retrieved April 19, 2017 from: http://www.prtconsulting.com/gallery11.html

Raney, S. & Young, S. (2004). 'Morgantown People Mover – Updated Description'. Paper presented at the Transport Research Board Annual Meeting, Washington D.C., 2005

Regeling lokaal spoor (2015, May 18). Retrieved May 23, 2017 from: http://wetten.overheid.nl/BWBR0036629/2015-12-01

Reichmut, J. (2010). *Analysis of the European air transport market. Airport accessibility in Europe.* Deutsches Zentrum für Luft- und Raumfahrt e.V. Retrieved from: https://ec.europa.eu/transport/sites/transport/files/modes/air/studies/doc/intermodality/2010-airport-accessibility-in-eu.pdf

RET (2016), *Verkenning busverbindingen Rotterdam The Hague Airport.*

RET (2017), *Missie*. Retrieved April 19, 2017 from: http://corporate.ret.nl/over-ret/missie.html

Rietveld, P. (2013). 'Appraisal methods for transport policy'. In Van Wee, B., Annema, J. A. & Banister, D. (Eds.). (2013). *The Transport System and Transport Policy: an introduction* (pp 329-252). Edward Elgar Publishing

Rijksoverheid (n.d.). *Ontwikkeling van* Schiphol Retrieved, May 30, 2017 from: https://www.rijksoverheid.nl/onderwerpen/luchtvaart/inhoud/schiphol

Romijn, G. & Renes, G. (2013). 'Algemene leidraad voor maatschappelijke kosten-batenanalyse'. Den Haag: De Swart

Rotterdam The Hague Airport (2015), *Overzicht verkeer en vervoer 2015 per maand*

Rotterdam The Hague Airport (2016), *Feiten en Cijfers 2015.* Retrieved from: https://www.rotterdamthehagueairport.nl/content/uploads/2016/08/Feiten-en-Cijfers-2015.pdf

Rotterdam The Hague Airport (2017-a), *Strategie*. Retrieved March 29, 2017 from: https://www.rotterdamthehagueairport.nl/onderneming/overons/strategie/

Rotterdam The Hague Airport (2017-b). *Reserveer hier uw auto.* Retrieved June 20, 2017 from: https://www.rotterdamthehagueairport.nl/reizigers/parkeren/reserveer-uw-parkeerplaats/

Royal Schiphol Group (2017). *Royal Schiphol Jaarverslag 2016*. Retrieved from: http://www.jaarverslagschiphol.nl/introductie/jaaroverzicht-2016

Ruijgrok, E. (2011). MKBA-kengetallen voor omgevingskwaliteiten: aanvulling en actualisering. Witteveen+Bos.

Schijnen, J. (2017). *Advies over draagvlak luchthavenbesluit Rotterdam The Hague Airport*. Retrieved from: https://www.zuid-holland.nl/onderwerpen/verkeer-vervoer/luchtvaart/the-hague-airport/verkenner-rotterdam/

Schiphol Real Estate (2017), *Over Schiphol Real Estate*. Retrieved March 29, 2017 from: http://kantooropschiphol.nl/over/

Schroten, A., Essen van, H., Aarnink, S., Verhoef, E. & Knockaert, J. (2014). Externe en infrastructuurkosten van verkeer. Een overzicht voor Nederland in 2010. Delft, CE Delft, June 2014.

Smit, R. & Krstic-Joksimovic, D. (2011). 'Het Nederlands Regionaal Model 2011, een excellent model voor de toekomst'. In *Proceedings of Colloquium Vervoersplanologisch Speurwerk*. Antwerp, Belgium, 24-25 November 2011.

Steenkamp, J.B., de Jong, M. & Baumgartner, H. (2009). 'Socially Desirable Response Tendencies in Survey Research'. In *Journal of Marketing Research Volume XLVI*, 2009

Steinbuch, M. (2017). *Tesla Model S battery degradation data.* Retrieved May 31, 2017 from: https://steinbuch.wordpress.com/2015/01/24/tesla-model-s-battery-degradation-data/

Steunpunt Economische Expertise (2017). Overzicht discontovoet per 1 april 2016. Retrieved June 20, 2016 from: https://www.rwseconomie.nl/discontovoet

Ultra Global PRT (2011), *Operations*. Retrieved from: http://www.ultraglobalprt.com/wp-content/uploads/2011/09/PDF_Operations.pdf

Verkeersonderneming (2016). *61 inzendingen voor Rotterdamse infrastructuur. Ondernemers tonen belangstelling en maken een business case.*

Wee van, B. (2013). 'Land use and transport. In Van Wee, B., Annema, J. A. & Banister, D. (Eds.). (2013). *The Transport System and Transport Policy: an introduction* (pp 78-100). Edward Elgar Publishing

Wet lokaal spoor (2013, July 10). Retrieved May 23, 2017, from: http://wetten.overheid.nl/BWBR0034363/2015-12-15

Wilson, A. (2014). *Handboek Verkeerslichtenregelingen.* Ede: CROW Media, 2014

Windfinder (2017). *Wind en weerstatistieken Rotterdam airport*. Retrieved May 31, 2017 from: https://www.windfinder.com/windstatistics/rotterdam_airport

Young, K., Wang, C., Wang, L. & Strunz, K. (2013). 'Electric vehicle battery technologies'. In Garcia-Valle, R. & Peças L., *Electric Vehicle Integration into Modern Power Networks* (pp 15-55). New York: Springer, 2013

Zuylen van, H., Knoop, V. & Li, J. (2010-a). 'A PRT system at SciencePort Holland and Airport Rotterdam/Den Haag'. Retrieved from http://www.transumofootprint.nl/upload/documents/03%20Projecten/Nieuwe%20vervoerssystemen/03%20Output/05%20Rapporten%20en%20verslagen/Eindrapport%20NiVes%20A%20PRT%20system%20at%20SciencePort%20Holland%20and%20Airport%20Rotterdam.pdf

Zuylen van, H., Andreasson, I., Hao, L., Chen, Y. & Jie, L. (2010-b). 'Optimizing the fleet size of a Personal Rapid Transit system: A case study in port of Rotterdam'. In Intelligent Transportation Systems (ITSC), 2010 13th International IEEE Conference on (pp 301-305). IEEE.

Personal communication for the stakeholder analysis:

M. Balk & J. Boelhouwers, senior planner and traffic planner municipality Rotterdam, personal communication, April 10, 2017.

S. van der Kleij, manager information, capacity and policy Rotterdam The Hague Airport, personal communication, March 28, 2017.

H. Kranenburg, transport developer RET, personal communication, April 12, 2017.

L. Lacroix, strategical advisor Metropole Region Rotterdam The Hague, personal communication, March 30, 2017.

C. Lonis, real estate developer Schiphol group, personal communication, April 6, 2017.

Personal communication for the political feasibility:

L. Harpe, city council member of Delft, portfolio traffic, transport, land affairs & real estate, waste policy, 'Spoorzone' and Delft Southeast, personal communication, June 23, 2016

F. Vermeulen, provincial executive of South Holland, portfolio traffic and transport, transport authority MRDH, communication and licensing, personal communication, June 26, 2017

Other personal communication:

R. Boersma, researcher TU Delft CiTG, personal communication, May 22, 2017

J. Philippen, head of the department research and development at VEKOMA, personal communication May 11, 2017.

J. Rijsdijk, controller traffic model Rotterdam, personal communication, March 15, 2017.

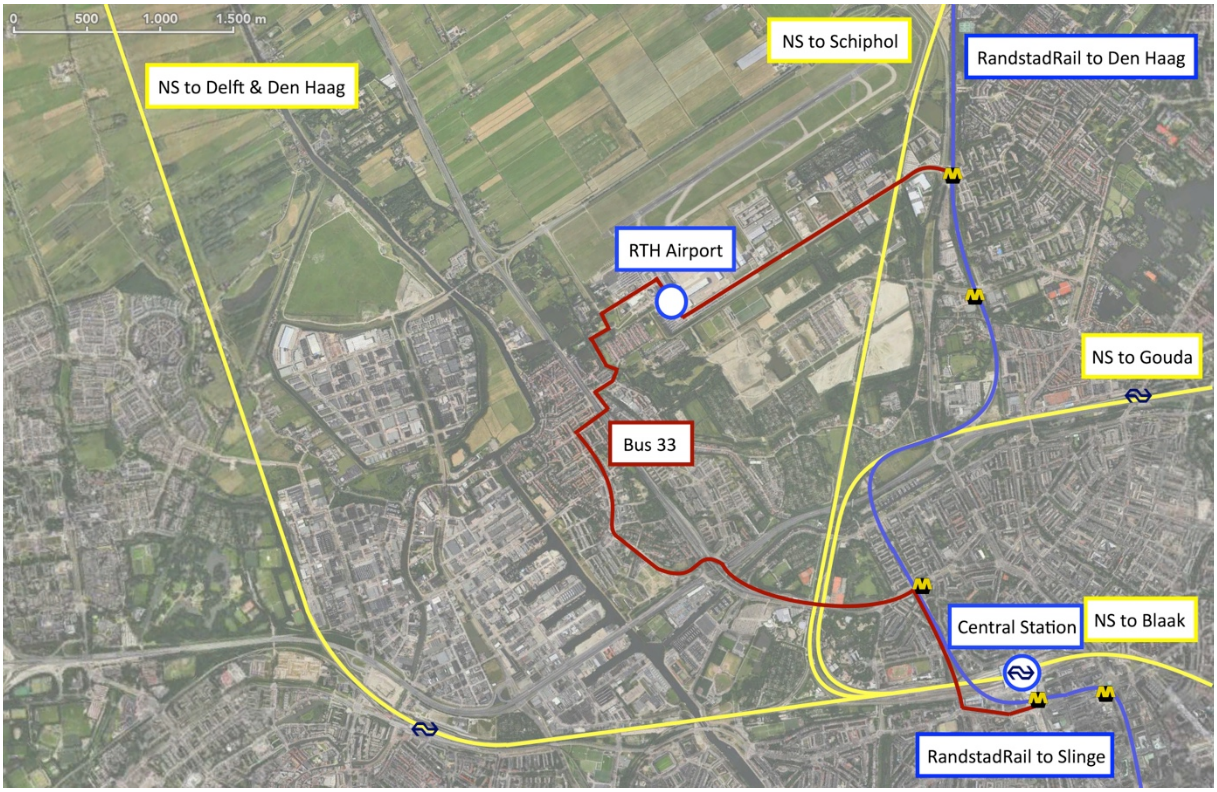
C. van de Weijer, director strategic area smart mobility TU Eindhoven, personal communication May 15, 2017.

11 Appendix

Appendix 1: Current public transport to and from the airport

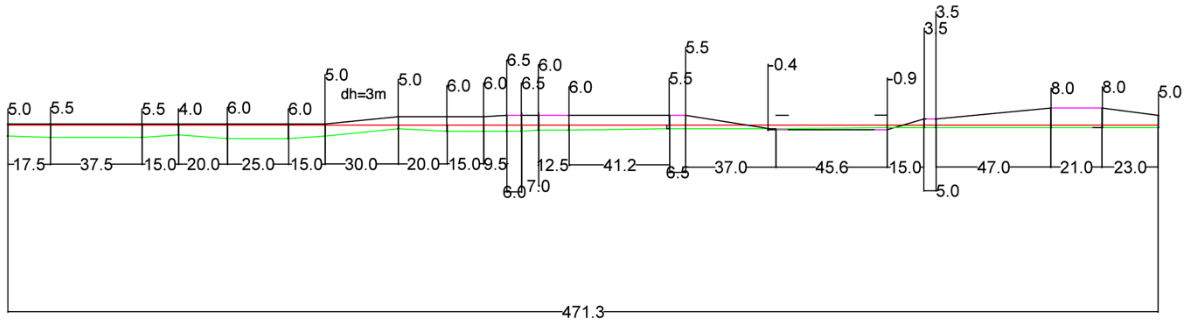
Origin	Bus/Metro/Train	Frequency	Transfers	Travel time
Rotterdam CS	Bus 33 to RTHA	6/hour	0	23 min
Rotterdam CS	RandstadRail E to Meijersplein + bus 33 to RTHA	6/hour	1	20 min
Den Haag CS	RandstadRail E to Meijersplein + bus 33 to RTHA	6/hour	1	41 min
Den Haag CS	Train to Rotterdam CS + bus 33 to RTHA	2/hour	1	50 min
Delft station	Train to Rotterdam CS + bus 33 to RTHA	6/hour	1	36 min
Delft station	Bus 40 to De Lugt + bus 33 to RTHA	3/hour	1	33 min

Source: 9292 (2017), the shortest travel time according to 9292 on Friday March 31, 2017



Source: own illustration and Metropoolregio Rotterdam Den Haag (2016)

Appendix 2: Height profile of the City Coaster track between Rotterdam The Hague Airport and Central Station



The horizontal distance in the height profile should be multiplied by 10. In green the ground level is displayed. Red shows 0m NAP and black is the City Coaster track. Pink shows sections in which a fly over or fly under is required.

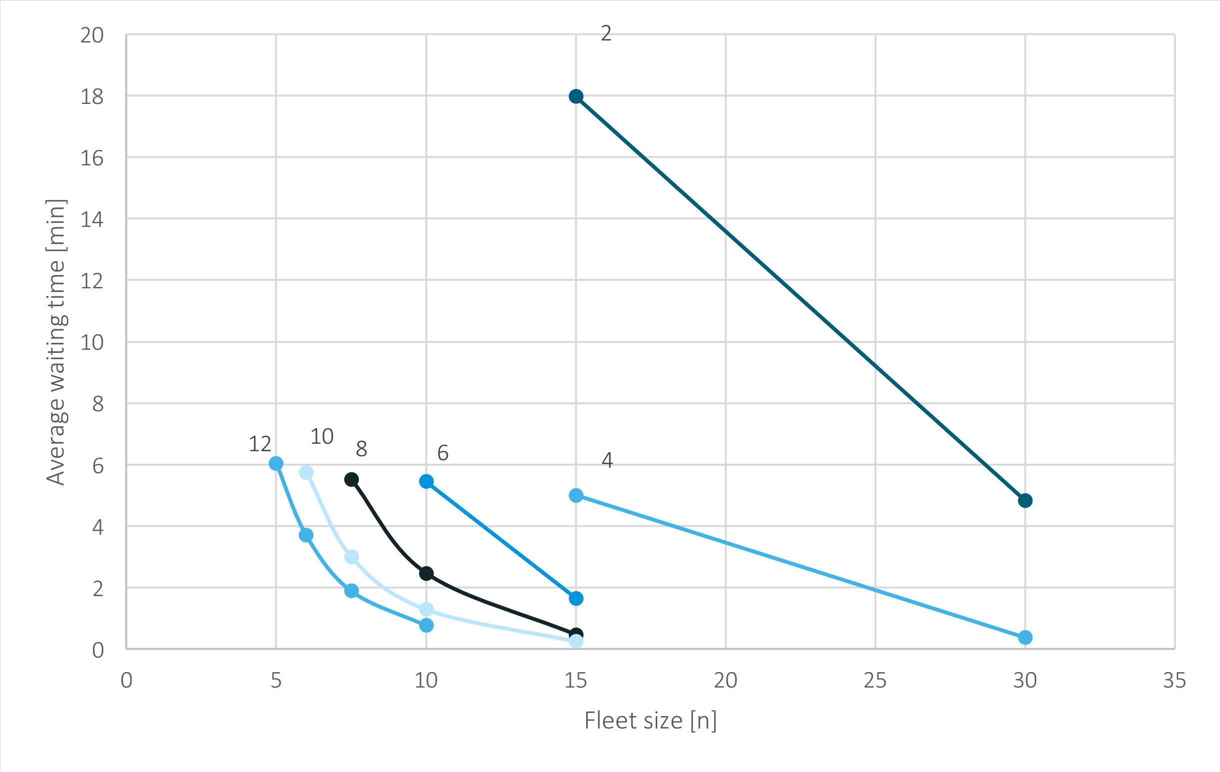
Appendix 3: Travel time calculation of the City Coaster

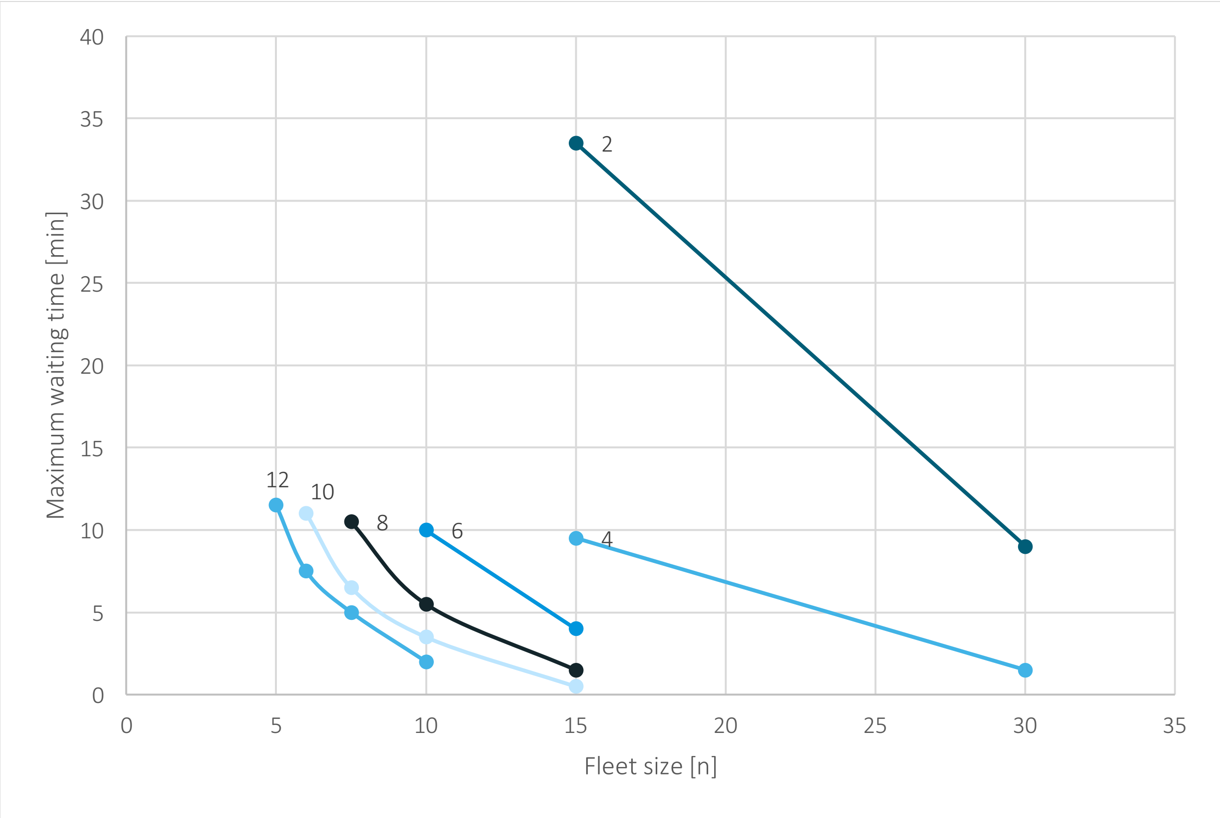
Distance	4713	m			
v	50	km/h			
Acceleration					
a	1,5	m/s2			
v(t)	50	km/h			
v(0)	0	km/h			
v(t)	v(o)+a*t		t	9,259259259	s
s(t)	s(o)+1/2*a*t^2+v(o)*t			64,30041152	m
Deceleration					
a	-1,5	m/s2			
v(t)	0	km/h			
v(0)	50	km/h			
v(t)	v(o)+a*t		t	9,259259259	s
s(t)	s(o)+1/2*a*t^2+v(o)*t			64,30041152	m
constant speed					
v	50	km/h	s	4584,399177	m
			t	330,0767407	s
Total					
			s	4713	m
			t	348,5952593	s
				5,809920988	min
			v_av	13,51997732	m/s
				48,67191836	km/h

Appendix 4: Passenger arrival at the City Coaster in case 100 passengers arrive according to the distribution of Figure 4-4.

Minutes after arrival	Passengers	Passengers per 30 seconds
0-10	0	0
10-15	25	2.5
15-20	50	5
25-30	20	2
30-35	5	0.5
35-40	0	0

Appendix 5: Average waiting time and maximum waiting time figures dependent on vehicle fleet





Appendix 6: Normal distribution of employees assuming 10% modal split

	250	pax/hour		
	normal dist	pax/5 min	per 1/2 min	per min
8.00-8.05	0,6	2	0,15	0,3
8.05-8-10	1,7	4	0,425	0,85
8.10-8.15	4,4	11	1,1	2,2
8.15-8.20	9,2	23	2,3	4,6
8.20-8.25	15	38	3,75	7,5
8.25-8.30	19,1	48	4,775	9,55
8.30-8.35	19,1	48	4,775	9,55
8.35-8.40	15	38	3,75	7,5
8.40-8.45	9,2	23	2,3	4,6
8.45-8.50	4,4	11	1,1	2,2
8.50-8.55	1,7	4	0,425	0,85
8.55-9.00	0,6	2	0,15	0,3
		250		

Appendix 7: Energy consumption of the City Coaster, first from RTHA – CS, second CS – RTHA

					pL =	1,2										
Air resistance	Fl = 1/2 pL * cw*A*vrel^2				vwind =	15,28										
Roll resistance	Fr = m*g*f				f=	0,01										
Roll resistance gradient	Fr = m*g*cos(a)*f				m =	2250										
Stijgingsweerstand	Fs = m*g*sin(a)				g =	9,81										
Accelertion resistance	FB = m *a				a =	1,50										
Power	P = F*v				A =	2,00										
Energy	E = P*t = F*v*t = F*s				cw =	0,80										
					v	13,89										
distance [m]	64	1236	300	350	95	732	370	456	150	50	470	210	166	64		
speed [m/s]	6,94	13,89	13,89	13,89	13,89	13,89	13,89	13,89	13,89	13,89	13,89	13,89	13,89	6,94		
gradient a (rad)			0,01		0,01		0,02		0,03		0,01		0,01	0,01		
cos a			1,00		1,00		1,00		1,00		1,00		1,00	1,00		
sin a			0,01		0,01		0,02		0,03		0,01		0,01	0,01		
Air resistance	474	817	817	817	817	817	817	817	817	817	817	817	817	817		
Roll resistance	221	221		221		221		221		221		221				
Roll resistance gradient			221		221		221		221		221		221	221		
Stijgingsweerstand			221		116		-352		647		258		-288	-288		
Accelertion resistance	3375															
SUM of Forces [N]	4070	1037	1258	1037	1154	1037	685	1037	1684	1037	1296	1037	749	749		
Power [W]	28262	14408	17474	14408	16022	14408	9520	14408	23396	14408	17995	14408	10410	5205		SUM
E [Ws]	260467	1282216	377447	363087	109590	759371	253646	473051	252780	51870	608985	217852	124416	47968		5182745
E [kWh]	0,07	0,36	0,10	0,10	0,03	0,21	0,07	0,13	0,07	0,01	0,17	0,06	0,03	0,01		1,44

					pL =	1,2										
Air resistance	Fl = 1/2 pL * cw*A*vrel^2				vwind =	15,28										
Roll resistance	Fr = m*g*f				f=	0,01										
Roll resistance gradient	Fr = m*g*cos(a)*f				m =	2250										
Stijgingsweerstand	Fs = m*g*sin(a)				g =	9,81										
Accelertion resistance	FB = m *a				a =	1,50										
Power	P = F*v				A =	2,00										
Energy	E = P*t = F*v*t = F*s				cw =	0,80										
					v	13,89										
distance [m]	64	166	210	470	50	150	456	370	732	95	350	300	1236	64		
speed [m/s]	6,94	13,89	13,89	13,89	13,89	13,89	13,89	13,89	13,89	13,89	13,89	13,89	13,89	6,94		
gradient a (rad)	0,01	0,01		0,01		0,03		0,02		0,01		0,01				
cos a	1,00	1,00		1,00		1,00		1,00		1,00		1,00				
sin a	0,01	0,01		0,01		0,03		0,02		0,01		0,01				
Air resistance	817	817	817	817	817	817	817	817	817	817	817	817	817	474		
Roll resistance			221		221		221		221		221		221	221		
Roll resistance gradient	221	221		221		221		221		221		221				
Stijgingsweerstand	288	288		-258		-647		352		-116		-221				
Accelertion resistance														3375		
SUM of Forces [N]	1325	1325	1037	779	1037	390	1037	1389	1037	921	1037	817	1037	4070		
Power [W]	9203	18406	14408	10821	14408	5418	14408	19296	14408	12795	14408	11343	14408	28262		SUM
E [Ws]	84816	219992	217852	366193	51870	58542	473051	514101	759371	87517	363087	245012	1282216	260467		4984087
E [kWh]	0,02	0,06	0,06	0,10	0,01	0,02	0,13	0,14	0,21	0,02	0,10	0,07	0,36	0,07		1,38

Appendix 8: Airport data 2015. Source: RTHA 2015

Passengers	January	February	March	April	May	June	July	August	September	October	November	December	**Total**	**Average/day**
Line flights	82454	97020	121975	125249	170753	161961	132713	137204	160693	138967	82370	81040	1492399	4088,8
Charter flight	2048	3575	3481	8249	19389	17751	23196	26339	16432	12590	2366	2220	137636	377,1
Sum	84502	100595	125456	133498	190142	179712	155909	163543	177125	151557	84736	83260	1630035	4465,8
Av. per day	2726	3593	4047	4450	6134	5990	5029	5276	5904	4889	2825	2686		

Flights	January	February	March	April	May	June	July	August	September	October	November	December	**Total**	**Average/day**
Line flights	1031	1133	1356	1381	1646	1661	1410	1349	1599	1470	1059	1008	16103	44,1
Charter flight	17	27	28	79	170	164	210	215	147	109	18	18	1202	3,3
sum	1048	1160	1384	1460	1816	1825	1620	1564	1746	1579	1077	1026	17305	47,4
Av. per day	34	41	45	49	59	61	52	50	58	51	36	33		

pax/flight	January	February	March	April	May	June	July	August	September	October	November	December	**Average**	
Line flights	80,0	85,6	90,0	90,7	103,7	97,5	94,1	101,7	100,5	94,5	77,8	80,4	91,4	
Charter flight	120,5	132,4	124,3	104,4	114,1	108,2	110,5	122,5	111,8	115,5	131,4	123,3	118,2	
													93,6	**Average flight**

Appendix 9: Origin Destination (OD) Matrices of bus line 33 in May 2015 per day. Source: data from Brands et al. (2015), OD Matrices designed by the author

Workday

	Bus stop from -> to	1 Rotterdam Centraal HA3940	1 Rotterdam Centraal perron AA HA3941	2 Bentinckplein HA2161	2 Bentinckplein HA2193	3 Blijdorp Metro HA2192	3 Blijdorp Metro HA2391	4 Vroesenpark HA2780	4 Vroesenpark HA2783	5 Blijdorpplein HA2781	5 Blijdorpplein HA2782	6 Gerard Sannehof HA2167	6 Gerard Sannehof HA2187	7 Van der Sasstraat HA2168	7 Van der Sasstraat HA2802	8 Hoornweg HA2169	8 Hoornweg HA2185	9 2e Hogenbanweg HA2170	9 2e Hogenbanweg HA2184	10 De Lugt HA2171	10 De Lugt HA2183	11 West-Sidelinge HA2172	11 West-Sidelinge HA2182	12 Burgemeester Bosstraat HA2174	12 Burgemeester Bosstraat HA2179	13 Noorderlaan HA2178	14 Vliegveldweg HA2175	14 Vliegveldweg HA2305	15 Gatwickbaan HA2560	15 Gatwickbaan HA2573	16 Rotterdam Airport HA2177	16 Rotterdam Airport HA2378	17 Lutonbaan HA2008	17 Lutonbaan HA2196	18 Gilze-Rijenstraat HA2022	18 Gilze-Rijenstraat HA2028	19 Meijersplein Metro HA2025	[0]	
1	Rotterdam Centraal HA3940	2	3	24			9	13		45		21		25		58		22		33		16		5			10		12		2	63	1		1		1	30	396
1	Rotterdam Centraal perron AA HA3941		2	62			19	16		101		43		66		133		56		77		34		20			27		27		3	153	3		1		3	57	903
2	Bentinckplein HA2161						6	1		5		4		6		11		4		7		2		1			1		1		1	3					1	3	57
2	Bentinckplein HA2193	72																																				1	73
3	Blijdorp Metro HA2192	36			3																																		39
3	Blijdorp Metro HA2391							2		10		5		6		14		5		5		2		1					2		1	6						2	61
4	Vroesenpark HA2780									11		4		6		11		4		4		1		1			1					2						1	46
4	Vroesenpark HA2783	19			1																																	1	21
5	Blijdorpplein HA2781													1		1		1		2		1															1	1	8
5	Blijdorpplein HA2782	133			5	13			4																													8	163
6	Gerard Sannehof HA2167															1		1																			1		3
6	Gerard Sannehof HA2187	46			2	8			1																													1	58
7	Van der Sasstraat HA2168															2		2		1		1					1					1					2		10
7	Van der Sasstraat HA2802	88			5	9			4		1																											1	108
8	Hoornweg HA2169																	2		12		6		6			3					2					8	1	40
8	Hoornweg HA2185	181			10	22			6		1		1		2																							4	227
9	2e Hogenbanweg HA2170																			14		9		6			5		1			6					9	2	52
9	2e Hogenbanweg HA2184	81			3	8			3		1				2		3																					2	103
10	De Lugt HA2171																												1			3					9	1	14
10	De Lugt HA2183	96			4	8			2		2		1		1		9		6																			2	131
11	West-Sidelinge HA2172																															1					4	1	6
11	West-Sidelinge HA2182	53			3	3									1		5		5		1																	1	72
12	Burgemeester Bosstraat HA2174																															1					6	1	8
12	Burgemeester Bosstraat HA2179	49			3	4			1		1		1		1		7		6		1																	2	76
13	Noorderlaan HA2178	17				1											4		7		1																	1	31
14	Vliegveldweg HA2175																																				3		3
14	Vliegveldweg HA2305	21			1	1											1		1																			2	27
15	Gatwickbaan HA2560																																				1		1
15	Gatwickbaan HA2573	10			1	1											1																					1	14
16	Rotterdam Airport HA2177	249			6	8			3		1						3		5		3		1		3			1			5							60	348
16	Rotterdam Airport HA2378	5																														4			1		123	12	145
17	Lutonbaan HA2008																																				25		25
17	Lutonbaan HA2196	4																	1																				5
18	Gilze-Rijenstraat HA2022																																				3		3
18	Gilze-Rijenstraat HA2028																																						0
19	Meijersplein Metro HA2025	6	2		1	1					1		2		1		6		7		8		3		7	3		2		1	100	1		36		25	3	11	227
		1168	7	86	48	87	34	32	24	172	8	77	5	110	8	231	39	97	38	155	14	72	4	40	10	3	48	3	44	1	112	246	4	36	3	25	203	210	3504

Saturday

		1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	14	14	15	15	16	16	17	17	18	18	19		
		Rotterdam Centraal HA3940	Rotterdam Centraal perron AA HA3941	Bentinckplein HA2161	Bentinckplein HA2193	Blijdorp Metro HA2192	Blijdorp Metro HA2391	Vroesenpark HA2780	Vroesenpark HA2783	Blijdorpplein HA2781	Blijdorpplein HA2782	Gerard Sannehof HA2167	Gerard Sannehof HA2187	Van der Sasstraat HA2168	Van der Sasstraat HA2802	Hoornweg HA2169	Hoornweg HA2185	2e Hogenbanweg HA2170	2e Hogenbanweg HA2184	De Lugt HA2171	De Lugt HA2183	West-Sidelinge HA2172	West-Sidelinge HA2182	Burgemeester Bosstraat HA2174	Burgemeester Bosstraat HA2179	Noorderlaan HA2178	Vliegveldweg HA2175	Vliegveldweg HA2305	Gatwickbaan HA2560	Gatwickbaan HA2573	Rotterdam Airport HA2177	Rotterdam Airport HA2378	Lutonbaan HA2008	Lutonbaan HA2196	Gilze-Rijenstraat HA2022	Gilze-Rijenstraat HA2028	Meijersplein Metro HA2025	[0]	
1	Rotterdam Centraal HA3940	5	1	6			5	14		58		6		19		38		16		21		9		4			10		4			50					1	23	290
1	Rotterdam Centraal perron AA HA3941		2	24			14	11		98		29		51		108		48		64		29		19			29		7			88	1					52	674
2	Bentinckplein HA2161						4	1		4		3		4		10		3		4		1										3						1	38
2	Bentinckplein HA2193	21																																				1	22
3	Blijdorp Metro HA2192	24			2																																	1	27
3	Blijdorp Metro HA2391							2		10		2		6		7		3		5		2		1			2					5						1	46
4	Vroesenpark HA2780									12		2		4		8		4		5		1		1			1					2						1	41
4	Vroesenpark HA2783	14			1																																		15
5	Blijdorpplein HA2781													1		2		1		2		1															1	1	9
5	Blijdorpplein HA2782	148			4	10			4		1																											11	178
6	Gerard Sannehof HA2167															1		2																					3
6	Gerard Sannehof HA2187	34			1	4			1																													1	41
7	Van der Sasstraat HA2168															1		1		1				1													1	1	6
7	Van der Sasstraat HA2802	67			3	6			4		1																											3	84
8	Hoornweg HA2169																	1		8		4		6			2					2					3	3	29
8	Hoornweg HA2185	150			8	12			8		2				1																							3	184
9	2e Hogenbanweg HA2170																			11		5		5			5					3					2	2	33
9	2e Hogenbanweg HA2184	82			3	7			2		1				1		1																					3	100
10	De Lugt HA2171																															1					3		4
10	De Lugt HA2183	83			2	6			1		2				1		6		3																			2	106
11	West-Sidelinge HA2172																															1					2		3
11	West-Sidelinge HA2182	36			1	4			1		1						2		3		1																	1	50
12	Burgemeester Bosstraat HA2174	1																														1					3	1	6
12	Burgemeester Bosstraat HA2179	42			1	5			1		1		1		1		6		4		1																		63
13	Noorderlaan HA2178	14															2		4		1																	2	23
14	Vliegveldweg HA2175																															1					3		4
14	Vliegveldweg HA2305	30															1		1																			3	35
15	Gatwickbaan HA2560																															1							1
15	Gatwickbaan HA2573																																					1	1
16	Rotterdam Airport HA2177	133			1	2			1		1						1		3		2				2			1		8	14							27	196
16	Rotterdam Airport HA2378	5																														6	1			1	51	5	69
17	Lutonbaan HA2008																																				3		3
17	Lutonbaan HA2196	2																	1																				3
18	Gilze-Rijenstraat HA2022																																						0
18	Gilze-Rijenstraat HA2028																																						0
19	Meijersplein Metro HA2025	2	2														4		4		2		2		4			3		1	34			6		14		4	82
		893	5	30	27	56	23	28	23	182	10	42	1	85	4	175	23	79	23	121	7	52	2	37	6	0	49	4	11	9	48	164	2	6	0	15	73	154	2469

Sunday

		1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	14	14	15	15	16	16	17	17	18	18	19		
	Stop from -> to	Rotterdam Centraal HA3940	Rotterdam Centraal perron AA HA3941	Bentinckplein HA2161	Bentinckplein HA2193	Blijdorp Metro HA2192	Blijdorp Metro HA2391	Vroesenpark HA2780	Vroesenpark HA2783	Blijdorpplein HA2781	Blijdorpplein HA2782	Gerard Sannehof HA2167	Gerard Sannehof HA2187	Van der Sasstraat HA2168	Van der Sasstraat HA2802	Hoornweg HA2169	Hoornweg HA2185	2e Hogenbanweg HA2170	2e Hogenbanweg HA2184	De Lugt HA2171	De Lugt HA2183	West-Sidelinge HA2172	West-Sidelinge HA2182	Burgemeester Bosstraat HA2174	Burgemeester Bosstraat HA2179	Noorderlaan HA2178	Vliegveldweg HA2175	Vliegveldweg HA2305	Gatwickbaan HA2560	Gatwickbaan HA2573	Rotterdam Airport HA2177	Rotterdam Airport HA2378	Lutonbaan HA2008	Lutonbaan HA2196	Gilze-Rijenstraat HA2022	Gilze-Rijenstraat HA2028	Meijersplein Metro HA2025	[0]	
1	Rotterdam Centraal HA3940	3	2	4			3	6		32		8		11		20		9		15		8		3			6		3		2	52					1	29	217
1	Rotterdam Centraal perron AA HA3941		4	23			18	25		124		24		35		67		36		50		21		17			20		7		3	175	1				1	114	765
2	Bentinckplein HA2161						2	1		2		1		3		3		3		3		1		1			1					4						1	26
2	Bentinckplein HA2193	19																																				1	20
3	Blijdorp Metro HA2192	34			2																																	1	37
3	Blijdorp Metro HA2391									7		3		2		3		2		4		3		2			1					8						3	38
4	Vroesenpark HA2780									3		1		3		8		2		3		1		1								2						2	26
4	Vroesenpark HA2783	27			1																																	1	29
5	Blijdorpplein HA2781													1		1		1		1							1					1						1	7
5	Blijdorpplein HA2782	151			2	6			3																													12	174
6	Gerard Sannehof HA2167																					1		1													1		3
6	Gerard Sannehof HA2187	22				4																																1	27
7	Van der Sasstraat HA2168																			1												1					1		3
7	Van der Sasstraat HA2802	50			1	3			2		1																												57
8	Hoornweg HA2169																			3		1		3			1					1					1		10
8	Hoornweg HA2185	87			4	5			5		1																											1	103
9	2e Hogenbanweg HA2170																			5		4		4			1					3					1		18
9	2e Hogenbanweg HA2184	59			1	4			3		1		1				1																					2	72
10	De Lugt HA2171																															2					2		4
10	De Lugt HA2183	54			2	3			2		1						3		2																			1	68
11	West-Sidelinge HA2172																		0								1					1					3		5
11	West-Sidelinge HA2182	33				3					1								1																			1	39
12	Burgemeester Bosstraat HA2174																															2					4		6
12	Burgemeester Bosstraat HA2179	32			1	5			2				2		1		3		3		1																	1	51
13	Noorderlaan HA2178	8											1				1		2																			1	13
14	Vliegveldweg HA2175																															1					2		3
14	Vliegveldweg HA2305	24				1			1																													2	28
15	Gatwickbaan HA2560																																						0
15	Gatwickbaan HA2573	3																																					3
16	Rotterdam Airport HA2177	232			4	9			4								3		3		2		1		1						2							34	295
16	Rotterdam Airport HA2378	9																														4					78	7	98
17	Lutonbaan HA2008																																				2		2
17	Lutonbaan HA2196	1																																				1	2
18	Gilze-Rijenstraat HA2022																																						0
18	Gilze-Rijenstraat HA2028																																						0
19	Meijersplein Metro HA2025	5						2	1	1	1	1	1		1	1	2	1	3		3		1		3			2		1	45	1		5		11	1	16	109
		853	6	27	18	43	23	34	23	169	6	38	5	55	2	103	13	54	14	85	6	40	2	32	4	0	32	2	10	1	52	258	1	5	0	11	98	233	2358

Appendix 10: Transfers at Meijersplein to Rotterdam The Hague Airport in May 2015. Source: Brands et al. (2015)

From …. to Meijersplein -> RTHA			
Den Haag CentraalMeijersplein Metro	485		
BeursMeijersplein Metro	322		
Rotterdam CentraalMeijersplein Metro	194		
Laan van NOIMeijersplein Metro	150		
ZuidpleinMeijersplein Metro	116		
WilhelminapleinMeijersplein Metro	93		
Pijnacker - ZuidMeijersplein Metro	93	93	RS
Leidschendam - VoorburgMeijersplein Metro	75	75	RS
Meijersplein MetroMeijersplein Metro	58		
LeidschenveenMeijersplein Metro	55	55	RS
RodenrijsMeijersplein Metro	51	51	RS
LeuvehavenMeijersplein Metro	51		
MelanchthonwegMeijersplein Metro	40		
MaashavenMeijersplein Metro	37		
SlingeMeijersplein Metro	33		
Voorburg t LooMeijersplein Metro	29	29	RS
StadhuisMeijersplein Metro	28		
PijnackerMeijersplein Metro	26	26	RS
Berkel - WestpolderMeijersplein Metro	25	25	RS
CoolhavenMeijersplein Metro	19		
RijnhavenMeijersplein Metro	17		
NootdorpMeijersplein Metro	16	16	RS
Spijkenisse CentrumMeijersplein Metro	13		
PoortugaalMeijersplein Metro	7		
Blijdorp MetroMeijersplein Metro	6		
SchenkelMeijersplein Metro	5		
VoorschoterlaanMeijersplein Metro	5		
HeemraadlaanMeijersplein Metro	5		
DelfshavenMeijersplein Metro	4		
CapelsebrugMeijersplein Metro	3		
PrinsenlaanMeijersplein Metro	3		
TussenwaterMeijersplein Metro	3		
GerdesiawegMeijersplein Metro	2		
ZalmplaatRotterdam Centraal	2		
ForeparkMeijersplein Metro	2	2	RS
Den Haag CentraalRotterdam Centraal	2		
BeursRotterdam Centraal	2		
DijkzigtMeijersplein Metro	2		
ZalmplaatMeijersplein Metro	2		
Capelle CentrumMeijersplein Metro	1		
EendrachtspleinMeijersplein Metro	1		
Bergse DorpsstraatMinervalaan	1		
PeppelwegWilgenplaslaan	1		
OostpleinMeijersplein Metro	1		
HoogvlietRotterdam Centraal	1		
ZaagmolenbrugRotterdam Centraal	1		
MathenesserbrugRotterdam Centraal	1		
PernisMeijersplein Metro	1		
Kralingse ZoomMeijersplein Metro	1		
Rotterdam AirportMeijersplein Metro	1		
OostersingelKastanjeplein	1		
Rotterdam CentraalVliegveldweg	1		
RuggewegBlijdorpplein	1		
Station AlexanderMeijersplein Metro	1		
MeidoornweideKastanjeplein	1		
HoogvlietMeijersplein Metro	1		
VroesenparkMeijersplein Metro	1		
Station BlaakMeijersplein Metro	1		
OosterflankMeijersplein Metro	1		
ParkwegMeijersplein Metro	1		
DonkersingelSchiehoven	1		
GrindwegDe Wilgenring	1		
De AkkersMeijersplein Metro	1		
Station Schiedam CentrumMeijersplein Metro	1		
	2106	372	1734	82,3

Appendix 11: Zonal Data Transport Model Rotterdam

Zonal Data	1600	1980	1981	2038
1: woningen	0	0	0	15
2: inwoners	0	0	0	34,67
3: inwon0034	0	0	0	14,51
4: bbv	0	0	0	16,28
5: llp12eo	0	0	0	0
6: detail	0	12,83	26,9	19,08
7: industrie	0	182,27	388,17	180,7
8: rest	0	64,77	1327,69	1395,68
9: arbeidspl_totaal	0	259,87	1742,76	1595,46
10: gebiedstype	3	3	3	3
11: intrazonaal	0	0	0	0

Appendix 12: Questions of the passenger interviews at the airport

Accessibility resea

SEND

QUESTIONS RESPONSES 16

Section 1 of 15

Accessibility research Rotterdam The Hague Airport

Rotterdam The Hague Airport, the City of Rotterdam and the metropole regio Rotterdam The Hague would like to improve the public transport accessibility of the airport. For my master thesis at Delft University of Technology I am therefore doing research to a faster public transport connection to the airport. Because you are visiting the airport today, you are member of the target group that eventually could use a faster connection.

To make sure that this faster connection fulfills your expectations and requirements, I set up this short interview to clarify your needs to this connection. The interview will take up to a maximum of 5 minutes and will be completely anonymous. No personal data is requested and the data is treated with extreme care.

If you have any questions about this research, please contact me at +31652196477 or l.j.m.meex@student.tudelft.nl. Thank you for your participation in this research.

Sincerely,
Luc Meex

After section 1 **Continue to next section**

Section 2 of 15

General information

Description (optional)

What is your age?

Short-answer text

What is your travel purpose?

- Leisure
- Business

What is the expected departure time of your flight?

Short-answer text

What does your traveling companionship look like?

- Alone
- With partner
- With family
- With a group
- Other...

Is this your in- or outbound journey?

- Outbound
- Inbound

After section 2 **Continue to next section**

Section 3 of 15

You are on your outbound journey

Description (optional)

How many days are you traveling?

Short-answer text

From which location did you depart on your way to the airport today?

Short-answer text

After section 3 **Go to section 5 (Transport mode)**

Section 4 of 15

You are on your inbound journey

Description (optional)

How long did you stay in the Netherlands?

Short-answer text

From which location did you depart on your way to the airport today?

Short-answer text

After section 4 **Go to section 5 (Transport mode)**

Section 5 of 15

Transport mode

Description (optional)

Which transport mode did you take to get to this airport?

- ◯ Car (parked at the airport facility)
- ◯ Car (parked at an external partner of the airport)
- ◯ Car (kiss & ride)
- ◯ Public transport
- ◯ Taxi
- ◯ Other...

After section 5 **Continue to next section**

Section 6 of 15

You traveled by public transport

Description (optional)

Which transport mode did you use? (multiple answers possible)

- ☐ Train
- ☐ Metro
- ☐ Tram
- ☐ Bus

At which station was your last transfer from one mode to the other?

- ◯ Rotterdam Central Station
- ◯ Metrostation Meijersplein
- ◯ Other...

What time did you start your trip to the airport?

Short-answer text

How long did your trip with public transport last? (minutes)

Short-answer text

What is your opinion about the current public transport connection?

Long-answer text

Why did you travel by public transport? (multiple answers possible)

- ☐ I didn't have a car available or I do not have a driving license
- ☐ No congestion
- ☐ No parking fees
- ☐ No fuel costs
- ☐ It is a convenient way of traveling
- ☐ It is cheap
- ☐ Other...

How should the public transport connection be improved? (multiple answers possible)

- ☐ The public transport is currently good as it is
- ☐ Shorter travel time
- ☐ More comfort
- ☐ Less transfers
- ☐ Cheaper
- ☐ More reliable
- ☐ Other...

On a scale from 0-10, would you recommend traveling by public transport to the airport to your family and friends?

	0	1	2	3	4	5	6	7	8	9	10	
don't recommend it	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	recommend it

After section 6 Go to section 10 (Within 6 minutes f...on to the airport)

Section 7 of 15

You travel by taxi

Description (optional)

Did you travel with another transport mode on your way to the airport before taking the taxi?

- ◯ Yes
- ◯ No

After section 7 Continue to next section

Section 8 of 15

You used another transport mode before taking the taxi to the airport

Description (optional)

Which other transport mode(s) did you use other than the taxi? (multiple answers possible)

- ☐ Car
- ☐ Train
- ☐ Metro
- ☐ Tram
- ☐ Bus
- ☐ Other...

On which location did you transfer to the taxi?

Short-answer text

After section 8 Go to section 10 (Within 6 minutes f...on to the airport)

Section 9 of 15

You traveled by car

Description (optional)

How long did your car trip take? (in minutes)

Short-answer text

How many extra travel time did you take into account because of possible delay? (e.g. because of congestion)

- ◯ 0 minutes
- ◯ 0 - 15 minutes
- ◯ 15 - 30 minutes
- ◯ 30 - 45 minutes
- ◯ 45 minutes or longer

After section 9 Go to section 10 (Within 6 minutes f...on to the airport)

Section 10 of 15

Within 6 minutes from Central Station to the airport

Description (optional)

Would you travel by public transport via Rotterdam Central Station if there would be a direct connection between Central Station and the airport which would take 6 minutes?

- ◯ Yes
- ◯ No

After section 10 Continue to next section

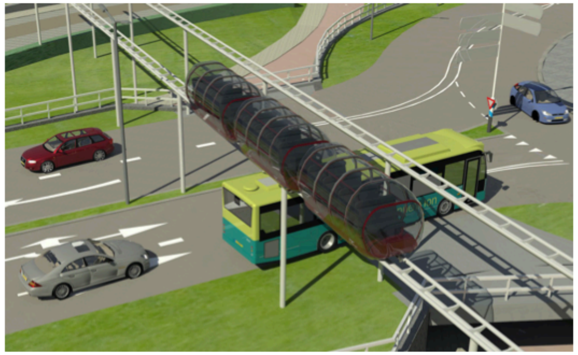
Section 11 of 15

You would not travel with a faster public transport connection

Why not? (multiple answers possible)

- [ ] I don't travel by public transport
- [ ] Traveling with luggage in public transport is inconvenient
- [ ] The public transport connection from my origin is not convenient
- [ ] Using the car is easier
- [ ] Public transport is too expensive
- [ ] Other...

The City Coaster



Title

The City Coaster (see image) are autonomous vehicles without a driver, suitable for 6 to 8 passengers and is riding a rail with a speed of 50 km/h. In the image you can see three independent vehicles, coupled together. There is enough space available for your luggage and you can enjoy the view on the skyline of Rotterdam. With minimal waiting time you board the City Coaster at Rotterdam Central Station and it will directly take you to the airport terminal. It is available 24 hours a day. The journey takes 6 minutes. If there are many people who want to use the City Coaster, you're in a vehicle together, in quiet moments you travel alone. On the stations, stewards are present to help you get in and out.

You just filled in that you would not travel by public transport via Rotterdam Central Station. Would you do that if you could use the City Coaster between Rotterdam Central Station and the airport?

- ◯ Yes
- ◯ No

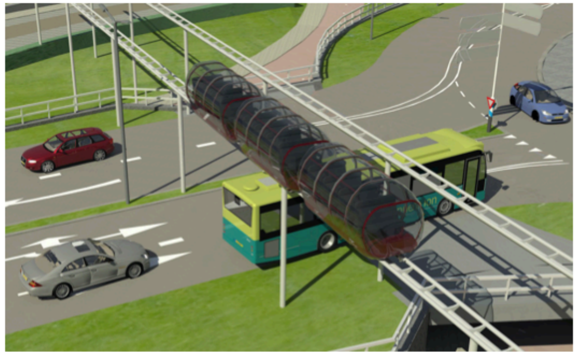
After section 11 **Go to section 12 (The City Coaster)**

Section 12 of 15

The City Coaster

Description (optional)

Image title



Title

The City Coaster (see image) are autonomous vehicles without a driver, suitable for 6 to 8 passengers and is riding a rail with a speed of 50 km/h. In the image you can see three independent vehicles, coupled together. There is enough space available for your luggage and you can enjoy the view on the skyline of Rotterdam. With minimal waiting time you board the City Coaster at Rotterdam Central Station and it will directly take you to the airport terminal. It is available 24 hours a day. The journey takes 6 minutes. If there are many people who want to use the City Coaster, you're in a vehicle together, in quiet moments you travel alone. On the stations, stewards are present to help you get in and out.

If there would be a City Coaster between Central Station and the airport, would you use it to travel to and from the airport?

- ◯ Yes
- ◯ No

After section 12 **Continue to next section**

Section 13 of 15

The City Coaster

Description (optional)

On a scale from 0-10, would you recommend traveling by public transport and with the City Coaster to the airport to your family and friends?

	0	1	2	3	4	5	6	7	8	9	10	
don't recommend it	○	○	○	○	○	○	○	○	○	○	○	recommend it

How much are you willing to pay per person to use the City Coaster between Central Station and the airport?

- ○ € 1,70 (current bus price)
- ○ € 3,00
- ○ € 5,00 (current taxi price per person by 4 occupants)
- ○ € 5,75
- ○ € 6,70 (current taxi price per person by 3 occupants)
- ○ € 10,00 (current taxi price per person by 2 occupants)
- ○ € 15,00
- ○ € 20,00 (current taxi price per person by 1 occupant)

What requirements would you have for a system as the City Coaster? Think about things as comfort, convenience, safety, etc.

Long-answer text

On a scale from 0-10, which public transport mode do you prefer as connection between Rotterdam Central Station and the airport? Compared are a bus (0) with the City Coaster (10).

	0	1	2	3	4	5	6	7	8	9	10	
Bus	○	○	○	○	○	○	○	○	○	○	○	City Coaster

The same question, but now a tram (0) is compared with the City Coaster (10).

	0	1	2	3	4	5	6	7	8	9	10	
Tram	○	○	○	○	○	○	○	○	○	○	○	City Coaster

The same question, but now a metro (0) is compared with the City Coaster (10).

	0	1	2	3	4	5	6	7	8	9	10	
Metro	○	○	○	○	○	○	○	○	○	○	○	City Coaster

The same question, but now a train (0) is compared with the City Coaster (10).

	0	1	2	3	4	5	6	7	8	9	10	
Train	○	○	○	○	○	○	○	○	○	○	○	City Coaster

After section 13 **Go to section 15 (Thank you for your participation!)**

Section 14 of 15

Section title (optional)

Description (optional)

Why would you not use the City Coaster? (multiple answers possible)

- ☐ There is no driver in the vehicle
- ☐ You are in the vehicle with other (unknown) people
- ☐ The speed of the City Coaster is too high
- ☐ You don't like small spaces (claustrophobia)
- ☐ You are afraid of heights
- ☐ Other...

After section 14 **Continue to next section**

Section 15 of 15

Thank you for your participation!

Description (optional)

If you have any comments on this interview please describe them below:

Long-answer text

If you want to have a chance to win the dinner voucher please leave your email address:

Short-answer text

Appendix 13: Cross tables interview data

	With City Coaster					
	No		Yes		Total	
With Public Transport		%		%		%
No	111	38.3	19	6.5	130	44.8
Yes	6	2.1	154	53.1	160	55.2
Total	**117**	**40.3**	**173**	**59.7**	**290**	

	With Public Transport					
	No		Yes		Total	
Travel Companion		%		%		%
Alone	28	9.7	74	25.5	102	35.2
With Partner	71	24.5	37	12.8	108	37.2
With Family	16	5.5	17	5.9	33	11.4
With Friends	14	4.8	26	9.0	40	13.8
With Colleague	1	0.3	6	2.0	7	2.4
Total	**130**	**44.8**	**160**	**55.2**	**290**	

	With Public Transport					
	No		Yes		Total	
Travel Purpose		%		%	Total	%
Business	12	4.1	35	12.1	47	16.2
Leisure	118	40.7	125	43.1	243	83.8
Total	**130**	**44.8**	**160**	**55.2**	**290**	

	Travel Purpose					
	Business		Leisure		Total	
Transport Mode		%		%	Total	%
Car (parked)	16	5.5	86	29.7	102	35.2
Car (Kiss + Ride)	8	2.8	80	27.6	88	30.3
Public Transport	13	4.5	64	22.1	77	26.6
Taxi	10	3.4	13	4.5	23	7.9
Total	**47**	**16.2**	**243**	**83.8**	**290**	

	With Public Transport					
	No		Yes		Total	
Transport Mode		**%**		**%**	**Total**	**%**
Car (parked)	65	22.4	37	12.8	102	35.2
Car (Kiss + Ride)	49	16.9	39	13.4	88	30.3
Public Transport	6	2.1	71	24.5	77	26.6
Taxi	10	3.4	13	4.5	23	7.9
Total	**130**	**44.8**	**160**	**55.2**	**290**	

	Transport Mode									
	Car (parked)		Car (Kiss + Ride)		Public Transport		Taxi		Total	
Departure Time		**%**		**%**		**%**		**%**	**Total**	**%**
06:55-08:59	15	5.2	16	5.5	6	2.1	5	1.7	42	14.5
09:00-10:59	5	1.7	5	1.7	11	3.8	3	1.0	24	8.3
11:00-12:59	19	6.6	15	5.2	15	5.2	2	0.7	51	17.6
13:00-14:59	23	7.9	20	6.9	22	7.6	5	1.7	70	24.1
15:00-16:59	18	6.2	17	5.8	6	2.1	5	1.7	46	15.9
17:00-18:59	16	5.5	9	3.1	14	4.8	2	0.7	41	14.1
19:00-20:59	6	2.1	6	2.1	3	1.0	1	0.4	16	5.5
Total	**102**	**35.2**	**88**	**30.3**	**77**	**26.6**	**23**	**7.9**	**290**	

	With Public Transport					
	No		Yes		Total	
Departure Time		**%**		**%**	**Total**	**%**
06:55-08:59	18	6.2	24	8.3	42	14.5
09:00-10:59	8	2.8	16	5.5	24	8.3
11:00-12:59	23	7.9	28	9.6	51	17.6
13:00-14:59	33	11.4	37	12.8	70	24.1
15:00-16:59	27	9.3	19	6.6	46	15.9
17:00-18:59	14	4.8	27	9.3	41	14.1
19:00-20:59	7	2.4	9	3.1	16	5.5
Total	**130**	**44.8**	**160**	**55.2**	**290**	

	With Public Transport					
	No		Yes		Total	
Age Category		%		%	Total	%
15-29	7	2.8	40	15.9	47	18.7
30-44	16	6.4	30	12.0	46	18.3
45-59	37	14.7	36	14.4	73	29.1
60+	52	20.7	33	13.1	85	33.9
Total	**112**	**44.6**	**139**	**55.4**	**251**	

	Transport Mode									
	Car (parked)		Car (Kiss + Ride)		Public Transport		Taxi		Total	
Age Category		%		%		%		%	Total	%
15-29	9	3.6	10	4.0	27	10.7	1	0.4	47	14.5
30-44	15	6.0	14	5.6	10	4.0	7	2.8	46	8.3
45-59	35	13.9	21	8.4	14	5.6	3	1.2	73	17.6
60+	30	12.0	33	13.1	15	6.0	7	2.8	85	24.1
Total	**89**	**35.5**	**78**	**31.1**	**66**	**26.3**	**18**	**7.2**	**251**	

Age

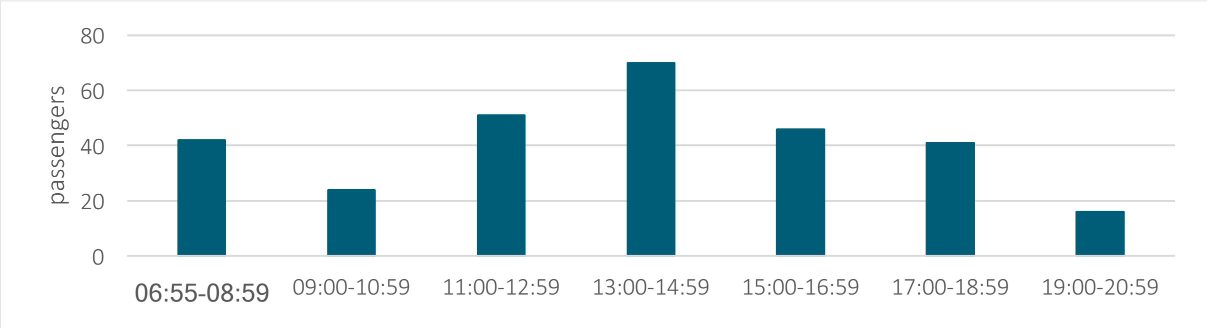
The average airport passenger is 49 years old (with a standard deviation of 17 years). The passengers have been categorized in four age categories of fifteen years: 15-29 years, 30-44 years, 45-59 years and older than 60. The two eldest groups are greatest, 73 respectively 85 passengers in the categories 45-59 and 60+.

Travel purpose

Of the 290 passengers, 47 passengers (16.2%) travelled for work purpose (Business), 83.8% of the passengers travelled for leisure. According to the airport, 20% of the passengers travel for business purposes (RTHA, 2016).

Departure time

The figure below shows the departure time of the population sample. As can be seen, the departing passengers are spread through the day, a peak can be observed for the morning (06:55-08:59) and in the early afternoon (13.00-14.59).



Travel companionship

A distinction is made between people travelling alone, with their partner, with family, with friends or with colleagues. Most people (n=108) travelled with their partner followed by people travelling alone (n=102). 40 People travelled with friends and 33 with family. Only 7 interviewees travelled with colleague

Appendix 15: Pearson's chi-square tests

With_Public_Transport * With_City_Coaster Crosstabulation

			With_City_Coaster No	With_City_Coaster Yes	Total
With_Public_Transport	No	Count	111	19	130
		Expected Count	52,4	77,6	130,0
	Yes	Count	6	154	160
		Expected Count	64,6	95,4	160,0
Total		Count	117	173	290
		Expected Count	117,0	173,0	290,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	198,599[a]	1	,000		
Continuity Correction[b]	195,222	1	,000		
Likelihood Ratio	231,816	1	,000		
Fisher's Exact Test				,000	,000
N of Valid Cases	290				

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 52,45.

b. Computed only for a 2x2 table

Travel_Companion * With_Public_Transport Crosstabulation

			With_Public_Transport No	With_Public_Transport Yes	Total
Travel_Companion	Alone	Count	28	74	102
		Expected Count	45,7	56,3	102,0
	With Colleague	Count	1	6	7
		Expected Count	3,1	3,9	7,0
	With Family	Count	16	17	33
		Expected Count	14,8	18,2	33,0
	With Friends	Count	14	26	40
		Expected Count	17,9	22,1	40,0
	With Partner	Count	71	37	108
		Expected Count	48,4	59,6	108,0
Total		Count	130	160	290
		Expected Count	130,0	160,0	290,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	35,932[a]	4	,000
Likelihood Ratio	36,940	4	,000
N of Valid Cases	290		

a. 2 cells (20,0%) have expected count less than 5. The minimum expected count is 3,14.

Departure_Time_Category * With_Public_Transport Crosstabulation

			With_Public_Transport		
			No	Yes	Total
Departure_Time_Category	06:55-08:59	Count	18	24	42
		Expected Count	18,8	23,2	42,0
	09:00-10:59	Count	8	16	24
		Expected Count	10,8	13,2	24,0
	11:00-12:59	Count	23	28	51
		Expected Count	22,9	28,1	51,0
	13:00-14:59	Count	33	37	70
		Expected Count	31,4	38,6	70,0
	15:00-16:59	Count	27	19	46
		Expected Count	20,6	25,4	46,0
	17:00-18:59	Count	14	27	41
		Expected Count	18,4	22,6	41,0
	19:00-20:59	Count	7	9	16
		Expected Count	7,2	8,8	16,0
Total		Count	130	160	290
		Expected Count	130,0	160,0	290,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6,977[a]	6	,323
Likelihood Ratio	7,032	6	,318
N of Valid Cases	290		

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 7,17.

Departure_Time_Category * Transport_Mode Crosstabulation

			Transport_Mode				
			Car (Kiss & Ride)	Car (parked)	Public Transport	Taxi	Total
Departure_Time_Category	06:55-08:59	Count	16	15	6	5	42
		Expected Count	12,7	14,8	11,2	3,3	42,0
	09:00-10:59	Count	5	5	11	3	24
		Expected Count	7,3	8,4	6,4	1,9	24,0
	11:00-12:59	Count	15	19	15	2	51
		Expected Count	15,5	17,9	13,5	4,0	51,0
	13:00-14:59	Count	20	23	22	5	70
		Expected Count	21,2	24,6	18,6	5,6	70,0
	15:00-16:59	Count	17	18	6	5	46
		Expected Count	14,0	16,2	12,2	3,6	46,0
	17:00-18:59	Count	9	16	14	2	41
		Expected Count	12,4	14,4	10,9	3,3	41,0
	19:00-20:59	Count	6	6	3	1	16
		Expected Count	4,9	5,6	4,2	1,3	16,0
Total		Count	88	102	77	23	290
		Expected Count	88,0	102,0	77,0	23,0	290,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	20,037[a]	18	,331
Likelihood Ratio	20,941	18	,282
N of Valid Cases	290		

a. 8 cells (28,6%) have expected count less than 5. The minimum expected count is 1,27.

Travel_Purpose * Transport_Mode Crosstabulation

			Transport_Mode				
			Car (Kiss & Ride)	Car (parked)	Public Transport	Taxi	Total
Travel_Purpose	Business	Count	8	16	13	10	47
		Expected Count	14,3	16,5	12,5	3,7	47,0
	Leisure	Count	80	86	64	13	243
		Expected Count	73,7	85,5	64,5	19,3	243,0
Total		Count	88	102	77	23	290
		Expected Count	88,0	102,0	77,0	23,0	290,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	15,924[a]	3	,001
Likelihood Ratio	13,337	3	,004
N of Valid Cases	290		

a. 1 cells (12,5%) have expected count less than 5. The minimum expected count is 3,73.

Transport_Mode * With_Public_Transport Crosstabulation

			With_Public_Transport		
			No	Yes	Total
Transport_Mode	Car (Kiss & Ride)	Count	49	39	88
		Expected Count	39,4	48,6	88,0
	Car (parked)	Count	65	37	102
		Expected Count	45,7	56,3	102,0
	Public Transport	Count	6	71	77
		Expected Count	34,5	42,5	77,0
	Taxi	Count	10	13	23
		Expected Count	10,3	12,7	23,0
Total		Count	130	160	290
		Expected Count	130,0	160,0	290,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	61,640[a]	3	,000
Likelihood Ratio	70,808	3	,000
N of Valid Cases	290		

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 10,31.

Travel_Purpose * With_Public_Transport Crosstabulation

			With_Public_Transport No	With_Public_Transport Yes	Total
Travel_Purpose	Business	Count	12	35	47
		Expected Count	21,1	25,9	47,0
	Leisure	Count	118	125	243
		Expected Count	108,9	134,1	243,0
Total		Count	130	160	290
		Expected Count	130,0	160,0	290,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	8,444[a]	1	,004		
Continuity Correction[b]	7,538	1	,006		
Likelihood Ratio	8,847	1	,003		
Fisher's Exact Test				,004	,003
N of Valid Cases	290				

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 21,07.

b. Computed only for a 2x2 table

Age_Category * With_Public_Transport Crosstabulation

			With_Public_Transport No	With_Public_Transport Yes	Total
Age_Category	15-29	Count	7	40	47
		Expected Count	21,0	26,0	47,0
	30-44	Count	16	30	46
		Expected Count	20,5	25,5	46,0
	45-59	Count	37	36	73
		Expected Count	32,6	40,4	73,0
	60+	Count	52	33	85
		Expected Count	37,9	47,1	85,0
Total		Count	112	139	251
		Expected Count	112,0	139,0	251,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	29,124[a]	3	,000
Likelihood Ratio	31,311	3	,000
N of Valid Cases	251		

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 20,53.

Age_Category * Transport_Mode Crosstabulation

			Transport_Mode				
			Car (Kiss & Ride)	Car (parked)	Public Transport	Taxi	Total
Age_Category	15-29	Count	10	9	27	1	47
		Expected Count	14,6	16,7	12,4	3,4	47,0
	30-44	Count	14	15	10	7	46
		Expected Count	14,3	16,3	12,1	3,3	46,0
	45-59	Count	21	35	14	3	73
		Expected Count	22,7	25,9	19,2	5,2	73,0
	60+	Count	33	30	15	7	85
		Expected Count	26,4	30,1	22,4	6,1	85,0
Total		Count	78	89	66	18	251
		Expected Count	78,0	89,0	66,0	18,0	251,0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	38,508[a]	9	,000
Likelihood Ratio	34,821	9	,000
N of Valid Cases	251		

a. 2 cells (12,5%) have expected count less than 5. The minimum expected count is 3,30.

Appendix 16: Power analysis for the chi-square test

The chi-square test can be used if the statistical power of the test is sufficient. This power can be calculated using G*Power 3.1. Outcome of the program is the minimum sample size and is dependent on effect size w, alpha, power (1-Beta error probability) and the degree of freedoms.

Effect size w has been chosen equal to 0.5 which implies a moderate effect. This because the dependencies studied with the chi-square test can be expected. Alpha is equal to 0.05 and the power 0.95. The degree of freedoms is chosen 5 (based on the chi-square test the maximum degree of freedoms is maximum 3).

The total sample size according to G*Power 3.1 is minimum.

Appendix 17: Logistic regression categories

Variables	Categories
Age	15-29
	30-44
	45-59
	60+
Travel Purpose	Leisure
	Business
Departure Time	06:55-08:59
	09:00-10:59
	11:00-12:59
	13:00-14:59
	15:00-16:59
	17:00-18:59
	19:00-20:59
Travel Companion	Alone
	With Partner
	With Family
	With Friends
	With Colleagues
Transport Mode	Car (parked)
	Car (Kiss+Ride)
	Taxi
	Public Transport

```
LOGISTIC REGRESSION VARIABLES With_CityCoaster
  /METHOD=BSTEP(LR) Age_Cat Travel_Purpose Departure_Time_CatTravel_Compan
ion Transport_Mode
  /CONTRAST (Age_Cat)=Indicator
  /CONTRAST (Travel_Purpose)=Indicator
  /CONTRAST (Departure_Time_Cat)=Indicator
  /CONTRAST (Travel_Companion)=Indicator
  /CONTRAST (Transport_Mode)=Indicator
  /SAVE=PRED PGROUP COOK LEVER DFBETA ZRESID
  /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).
```

Logistic Regression

Notes

Output Created		04-JUN-2017 17:26:40
Comments		
Input	Data	/Users/lucmeex/Desktop/Statistics nieuw/FINAL1.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	251
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing

Notes

Syntax		LOGISTIC REGRESSION VARIABLES With_CityCoaster /METHOD=BSTEP(LR) Age_Cat Travel_Purpose Departure_Time_Cat Travel_Companion Transport_Mode /CONTRAST (Age_Cat) =Indicator /CONTRAST (Travel_Purpose) =Indicator /CONTRAST (Departure_Time_Cat) =Indicator /CONTRAST (Travel_Companion) =Indicator /CONTRAST (Transport_Mode) =Indicator /SAVE=PRED PGROUP COOK LEVER DFBETA ZRESID /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).
Resources	Processor Time	00:00:00,07
	Elapsed Time	00:00:00,00
Variables Created or Modified	PRE_2	Predicted probability
	PGR_2	Predicted group
	COO_2	Analog of Cook's influence statistics
	LEV_2	Leverage value
	ZRE_2	Normalized residual
	DFB0_2	DFBETA for constant
	DFB1_2	DFBETA for Age_Cat(1)
	DFB2_2	DFBETA for Age_Cat(2)
	DFB3_2	DFBETA for Age_Cat(3)
	DFB4_2	DFBETA for Transport_Mode(1)
	DFB5_2	DFBETA for Transport_Mode(2)
	DFB6_2	DFBETA for Transport_Mode(3)

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	251	100,0
	Missing Cases	0	,0
	Total	251	100,0
Unselected Cases		0	,0
Total		251	100,0

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

Dependent Variable Encoding

Original Value	Internal Value
No	0
Yes	1

Categorical Variables Codings

			Parameter coding			
		Frequency	(1)	(2)	(3)	(4)
Departure_Time_Cat	09:00-10:59	23	1,000	,000	,000	,000
	11:00-12:59	46	,000	1,000	,000	,000
	13:00-14:59	65	,000	,000	1,000	,000
	15:00-16:59	39	,000	,000	,000	1,000
	17:00-18:59	35	,000	,000	,000	,000
	19:00-20:59	11	,000	,000	,000	,000
	06:55-08:59	32	,000	,000	,000	,000
Travel_Companion	With Partner	94	1,000	,000	,000	,000
	With Family	31	,000	1,000	,000	,000
	With Friends	36	,000	,000	1,000	,000
	With Colleague	7	,000	,000	,000	1,000
	Alone	83	,000	,000	,000	,000
Transport_Mode	Car Parked	89	1,000	,000	,000	
	Car Kiss+Ride	78	,000	1,000	,000	
	Taxi	18	,000	,000	1,000	
	Public Transport	66	,000	,000	,000	
Age_Cat	30-44	46	1,000	,000	,000	
	45-59	73	,000	1,000	,000	
	60+	85	,000	,000	1,000	
	15-29	47	,000	,000	,000	
Travel_Purpose	Business	38	1,000			
	Leisure	213	,000			

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	96,673	17	,000
	Block	96,673	17	,000
	Model	96,673	17	,000
Step 2[a]	Step	-7,982	6	,239
	Block	88,691	11	,000
	Model	88,691	14	,000
Step 3[a]	Step	-,814	1	,367
	Block	87,877	10	,000
	Model	87,877	8	,000
Step 4[a]	Step	-6,148	4	,188
	Block	81,729	6	,000
	Model	81,729	7	,000

a. A negative Chi-squares value indicates that the Chi-squares value has decreased from the previous step.

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	242,434[a]	,320	,431
2	250,416[a]	,298	,402
3	251,230[a]	,295	,399
4	257,378[a]	,278	,375

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

Classification Table[a]

	Observed		Predicted With_CityCoaster No	Predicted With_CityCoaster Yes	Percentage Correct
Step 1	With_CityCoaster	No	77	25	75,5
		Yes	33	116	77,9
	Overall Percentage				76,9
Step 2	With_CityCoaster	No	74	28	72,5
		Yes	39	110	73,8
	Overall Percentage				73,3
Step 3	With_CityCoaster	No	67	35	65,7
		Yes	33	116	77,9
	Overall Percentage				72,9
Step 4	With_CityCoaster	No	79	23	77,5
		Yes	47	102	68,5
	Overall Percentage				72,1

a. The cut value is ,500

Variables in the Equation

		B	S.E.	Wald	df	Sig.
Step 1[a]	Age_Cat			4,949	3	,176
	Age_Cat(1)	-,081	,618	,017	1	,896
	Age_Cat(2)	-,473	,586	,650	1	,420
	Age_Cat(3)	-,978	,582	2,821	1	,093
	Travel_Purpose(1)	,821	,565	2,111	1	,146
	Departure_Time_Cat			7,649	6	,265
	Departure_Time_Cat(1)	-1,887	,779	5,861	1	,015
	Departure_Time_Cat(2)	-1,135	,603	3,545	1	,060
	Departure_Time_Cat(3)	-,990	,534	3,437	1	,064
	Departure_Time_Cat(4)	-1,308	,579	5,111	1	,024
	Departure_Time_Cat(5)	-,853	,628	1,841	1	,175
	Departure_Time_Cat(6)	-1,024	,815	1,579	1	,209
	Travel_Companion			7,119	4	,130
	Travel_Companion(1)	-,655	,436	2,252	1	,133
	Travel_Companion(2)	,449	,579	,601	1	,438
	Travel_Companion(3)	,551	,560	,969	1	,325
	Travel_Companion(4)	,417	1,001	,174	1	,677
	Transport_Mode			23,911	3	,000
	Transport_Mode(1)	-3,741	,787	22,623	1	,000
	Transport_Mode(2)	-3,720	,797	21,806	1	,000
	Transport_Mode(3)	-3,119	,932	11,207	1	,001
	Constant	5,008	,970	26,672	1	,000

Page 7

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	Age_Cat	25,401	3	,000
		Age_Cat(1)	2,430	1	,119
		Age_Cat(2)	,436	1	,509
		Age_Cat(3)	15,415	1	,000
		Travel_Purpose(1)	5,335	1	,021
		Departure_Time_Cat	5,445	6	,488
		Departure_Time_Cat(1)	,360	1	,549
		Departure_Time_Cat(2)	,053	1	,818
		Departure_Time_Cat(3)	,015	1	,903
		Departure_Time_Cat(4)	3,340	1	,068
		Departure_Time_Cat(5)	1,430	1	,232
		Departure_Time_Cat(6)	,922	1	,337
		Travel_Companion	23,783	4	,000
		Travel_Companion(1)	22,340	1	,000
		Travel_Companion(2)	,054	1	,815
		Travel_Companion(3)	2,881	1	,090
		Travel_Companion(4)	,435	1	,510
		Transport_Mode	54,419	3	,000
		Transport_Mode(1)	13,808	1	,000
		Transport_Mode(2)	9,851	1	,002
		Transport_Mode(3)	,025	1	,875
	Overall Statistics		77,519	17	,000

Block 1: Method = Backward Stepwise (Likelihood Ratio)

Page 5

Variables in the Equation

		B	S.E.	Wald	df	Sig.
Step 2[a]	Age_Cat			5,523	3	,137
	Age_Cat(1)	-,205	,593	,120	1	,729
	Age_Cat(2)	-,553	,561	,970	1	,325
	Age_Cat(3)	-1,073	,564	3,621	1	,057
	Travel_Purpose(1)	,485	,542	,800	1	,371
	Travel_Companion			4,689	4	,321
	Travel_Companion(1)	-,559	,416	1,803	1	,179
	Travel_Companion(2)	,123	,533	,053	1	,818
	Travel_Companion(3)	,384	,529	,527	1	,468
	Travel_Companion(4)	,275	,983	,078	1	,780
	Transport_Mode			22,618	3	,000
	Transport_Mode(1)	-3,562	,769	21,431	1	,000
	Transport_Mode(2)	-3,518	,774	20,671	1	,000
	Transport_Mode(3)	-2,966	,907	10,696	1	,001
	Constant	4,024	,855	22,126	1	,000
Step 3[a]	Age_Cat			6,397	3	,094
	Age_Cat(1)	-,179	,591	,092	1	,762
	Age_Cat(2)	-,528	,560	,889	1	,346
	Age_Cat(3)	-1,113	,563	3,905	1	,048
	Travel_Companion			6,052	4	,195
	Travel_Companion(1)	-,687	,391	3,093	1	,079
	Travel_Companion(2)	-,025	,509	,002	1	,961
	Travel_Companion(3)	,285	,515	,306	1	,580
	Travel_Companion(4)	,517	,930	,309	1	,578
	Transport_Mode			22,765	3	,000
	Transport_Mode(1)	-3,538	,768	21,227	1	,000
	Transport_Mode(2)	-3,518	,773	20,699	1	,000
	Transport_Mode(3)	-2,856	,894	10,213	1	,001
	Constant	4,152	,850	23,872	1	,000
Step 4[a]	Age_Cat			13,148	3	,004
	Age_Cat(1)	-,319	,576	,307	1	,579
	Age_Cat(2)	-,838	,528	2,523	1	,112
	Age_Cat(3)	-1,533	,523	8,587	1	,003
	Transport_Mode			23,755	3	,000
	Transport_Mode(1)	-3,587	,760	22,251	1	,000
	Transport_Mode(2)	-3,510	,762	21,202	1	,000
	Transport_Mode(3)	-2,876	,887	10,501	1	,001
	Constant	4,223	,822	26,410	1	,000

Variables in the Equation

		Exp(B)
Step 2[a]	Age_Cat	
	Age_Cat(1)	,815
	Age_Cat(2)	,575
	Age_Cat(3)	,342
	Travel_Purpose(1)	1,624
	Travel_Companion	
	Travel_Companion(1)	,572
	Travel_Companion(2)	1,131
	Travel_Companion(3)	1,468
	Travel_Companion(4)	1,316
	Transport_Mode	
	Transport_Mode(1)	,028
	Transport_Mode(2)	,030
	Transport_Mode(3)	,052
	Constant	55,899
Step 3[a]	Age_Cat	
	Age_Cat(1)	,836
	Age_Cat(2)	,590
	Age_Cat(3)	,329
	Travel_Companion	
	Travel_Companion(1)	,503
	Travel_Companion(2)	,975
	Travel_Companion(3)	1,330
	Travel_Companion(4)	1,677
	Transport_Mode	
	Transport_Mode(1)	,029
	Transport_Mode(2)	,030
	Transport_Mode(3)	,057
	Constant	63,592
Step 4[a]	Age_Cat	
	Age_Cat(1)	,727
	Age_Cat(2)	,432
	Age_Cat(3)	,216
	Transport_Mode	
	Transport_Mode(1)	,028
	Transport_Mode(2)	,030
	Transport_Mode(3)	,056
	Constant	68,248

a. Variable(s) entered on step 1: Age_Cat, Travel_Purpose, Departure_Time_Cat, Travel_Companion, Transport_Mode.

Model if Term Removed

Variable		Model Log Likelihood	Change in -2 Log Likelihood	df	Sig. of the Change
Step 1	Age_Cat	-123,720	5,007	3	,171
	Travel_Purpose	-122,307	2,180	1	,140
	Departure_Time_Cat	-125,208	7,982	6	,239
	Travel_Companion	-124,880	7,327	4	,120
	Transport_Mode	-146,842	51,251	3	,000
Step 2	Age_Cat	-128,018	5,621	3	,132
	Travel_Purpose	-125,615	,814	1	,367
	Travel_Companion	-127,576	4,737	4	,315
	Transport_Mode	-150,115	49,813	3	,000
Step 3	Age_Cat	-128,875	6,520	3	,089
	Travel_Companion	-128,689	6,148	4	,188
	Transport_Mode	-150,431	49,631	3	,000
Step 4	Age_Cat	-135,654	13,930	3	,003
	Transport_Mode	-156,011	54,643	3	,000

Variables not in the Equation

			Score	df	Sig.
Step 2[a]	Variables	Departure_Time_Cat	7,972	6	,240
		Departure_Time_Cat(1)	1,961	1	,161
		Departure_Time_Cat(2)	,080	1	,777
		Departure_Time_Cat(3)	,007	1	,934
		Departure_Time_Cat(4)	,988	1	,320
		Departure_Time_Cat(5)	,076	1	,783
		Departure_Time_Cat(6)	,012	1	,915
	Overall Statistics		7,972	6	,240
Step 3[b]	Variables	Travel_Purpose(1)	,805	1	,369
		Departure_Time_Cat	6,564	6	,363
		Departure_Time_Cat(1)	1,583	1	,208
		Departure_Time_Cat(2)	,083	1	,773
		Departure_Time_Cat(3)	,002	1	,963
		Departure_Time_Cat(4)	,860	1	,354
		Departure_Time_Cat(5)	,052	1	,820
		Departure_Time_Cat(6)	,008	1	,928
	Overall Statistics		8,799	7	,267
Step 4[c]	Variables	Travel_Purpose(1)	2,193	1	,139
		Departure_Time_Cat	3,559	6	,736
		Departure_Time_Cat(1)	,829	1	,363
		Departure_Time_Cat(2)	,002	1	,964
		Departure_Time_Cat(3)	,003	1	,957

Variables not in the Equation

		Score	df	Sig.
	Departure_Time_Cat(4)	,767	1	,381
	Departure_Time_Cat(5)	,056	1	,813
	Departure_Time_Cat(6)	,050	1	,824
	Travel_Companion	6,188	4	,186
	Travel_Companion(1)	5,554	1	,018
	Travel_Companion(2)	,114	1	,736
	Travel_Companion(3)	1,601	1	,206
	Travel_Companion(4)	,677	1	,411
Overall Statistics		14,514	11	,206

a. Variable(s) removed on step 2: Departure_Time_Cat.

b. Variable(s) removed on step 3: Travel_Purpose.

c. Variable(s) removed on step 4: Travel_Companion.

Appendix 19: Personnel costs

The City Coaster has two stations which should be operated by personnel between 4.30 A.M. and 12.30 A.M. 7 days per week. Therefore, 140 work hours per station are required per week. To achieve this, 7 employees (40 working hours per week) are required. Next to that, it is assumed that one employee is responsible for maintenance. According to the collective employee agreement (Dutch: CAO) of public transport companies (FNV, 2017), the wage costs can be estimated to 35,000 Euro per employee. The yearly personnel costs can then be estimated to 280,000 Euro.

For the mode choice to the airport to following costs are identified: travel time costs, travel costs and parking costs. The travel time costs can be calculated by applying the value of time (VOT), the travel costs consist of the costs of using a car and the parking costs. The costs of using a car are estimated by the National Institute for Budget Information (NIBUD) on 0.40 € per vehicle kilometer (NIBUD, 2017). The parking costs could be derived from the website of the airport. For Parking 1 and Parking 3, the largest parking areas at the airport, the costs are € 27.50 for one day, for each additional day a fee of 5 Euro is charged (RTHA, 2017-b). The interview data showed that people parking or using Kiss & Ride to the airport and willing to use the City Coaster have specific (average) characteristics as can be seen in the table below.

	Car (parked)	Car (Kiss & Ride)
Vehicle occupancy [pax/vehicle]	2.2	2.1
Travel duration [days]	7	8
Travel time car [min]	45	39
Distance car [km]	58	43

Based on the derived information from the interviews, the generalized transport costs (GTC) for airport passengers can be calculated in case they use the car (parked or K&R) or the City Coaster. In these generalized transport costs only travel time costs, travel costs, parking costs and time costs of the driver in case of Kiss & Ride are considered. The calculation of the GTC can be found on the next pages. The difference in GTC is the 'profit' for the passenger, also defined as the consumer surplus (Van Wee, 2013). For Kiss & Ride passengers the average consumer surplus is € 6.66 and for car parked passengers € 19.64. With this consumer surplus, the benefits for passengers have been calculated.

Appendix 21: Micro-economy theory calculations

Parked																											
Origin	Count	TT car	TT PT	Via CS	TT CC	TT gain		distance	distance*count	TT car*count		Price PT to CS	Price CC	Costs PT	TT Costs	Total Costs PT		TT Costs	Car Costs	TT Cost driver	Total Costs K+R		Costs PT*count	Costs Car*count	Consumer Surplus		Price PT to CS*count
Amsterdam	4	50	90	Ja	75	-25		70	280	200		15	3	18	19,38	37,58		12,92	12,73	13,07	38,71		150,3	154,8			60,8
Antwerpen	2	70	95	Ja	80	-10		115	230	140		19	3	22	20,67	42,67		18,08	20,91	13,07	52,06		85,33	104,1			38
Arnhem	1	80	120	Ja	105	-25		115	115	80		19	3	22	27,13	48,83		20,67	20,91	13,07	54,64		48,83	54,64			18,7
Barendrecht	1	20	40	Ja	25	-5		25	25	20		2,8	3	5,8	6,46	12,26		5,17	4,55	13,07	22,78		12,26	22,78			2,8
Borne	1	120	180	Ja	165	-45		190	190	120		24	3	27	42,63	69,63		31,00	34,55	13,07	78,61		69,63	78,61			24
De lier	1	20	75	Ja	60	-40		25	25	20		7	3	10	15,50	25,49		5,17	4,55	13,07	22,78		25,49	22,78			6,99
Den Haag	1	30	55	Ja	40	-10		23	23	30		5,8	3	8,8	10,33	19,14		7,75	4,18	13,07	25,00		19,14	25,00			5,81
Dordrecht	2	30	50	Ja	35	-5		35	70	60		4,4	3	7,4	9,04	16,44		7,75	6,36	13,07	27,18		32,88	54,36			8,8
Ermelo	1	85	150	Ja	135	-50		125	125	85		17	3	20	34,88	54,88		21,96	22,73	13,07	57,75		54,88	57,75			17
Groningen	1	140	180	Ja	165	-25		250	250	140		26	3	29	42,63	71,93		36,17	45,45	13,07	94,69		71,93	94,69			26,3
Houten	1	55	120	Ja	105	-50		70	70	55		12	3	15	27,13	41,83		14,21	12,73	13,07	40,00		41,83	40,00			11,7
Lopikerkapel	1	45	130	Ja	115	-70		65	65	45		9,6	3	13	29,71	42,27		11,63	11,82	13,07	36,51		42,27	36,51			9,56
Niewekerk ad Ijssel	3	25	45	Ja	30	-5		20	60	75		3,5	3	6,5	7,75	14,25		6,46	3,64	13,07	23,16		42,75	69,49			10,5
Rijswijk	1	30	45	Ja	30	0		15	15	30		4,2	3	7,2	7,75	14,95		7,75	2,73	13,07	23,55		14,95	23,55			4,2
Rotterdam	6	20	35	Ja	20	0		7,5	45	120		0	3	3	5,17	8,17		5,17	1,36	13,07	19,60		49,00	117,6			0
Utrecht	1	45	70	Ja	55	-10		65	65	45		10	3	13	14,21	27,51		11,63	11,82	13,07	36,51		27,51	36,51			10,3
Veere	1	80	170	Ja	155	-75		120	120	80		22	3	25	40,04	65,02		20,67	21,82	13,07	55,55		65,02	55,55			21,98
Voorschoten	1	30	65	Ja	50	-20		30	30	30		6,5	3	9,5	12,92	22,42		7,75	5,45	13,07	26,27		22,42	26,27			6,5
Wassenaar	1	35	80	Ja	65	-30		30	30	35		7,5	3	11	16,79	27,32		9,04	5,45	13,07	27,56		27,32	27,56			7,53
Zwijndrecht	1	35	50	Ja	35	0		30	30	35		4	3	7	9,04	16,04		9,04	5,45	13,07	27,56		16,04	27,56			4
Total	**32**							**aver**	**58**	**45**												**averag**	**28,74**	**35,32**	**6,58**	**aver**	**9,23**

K+R

Origin	Count	TT car	TT PT	Via CS	TT CC	TT gain		distance	distance*count	TT car*count		Price PT to CS	Price CC	Costs PT	TT Costs	Total Costs PT		TT Costs	Car Costs	TT Cost driver	Total Costs K+R		Costs PT*count	Costs Car*count	Consumer Surplus		Price PT to CS*count
Arnhem	3	75	120	Yes	105	-30		115	345	225		19	3	22	27,13	48,83		19,38	43,81	8,93	72,11		146,5	216,3			56,1
Capelle ad Ijssel	1	20	35	Yes	20	0		17	17	20		2,8	3	5,8	5,17	10,97		5,17	6,48	2,38	14,02		10,97	14,02			2,8
Den Haag	4	25	55	Yes	40	-15		23	92	100		5,8	3	8,8	10,33	19,14		6,46	8,76	2,98	18,20		76,57	72,79			23,24
Dordrecht	2	30	45	Yes	30	0		35	70	60		4,4	3	7,4	7,75	15,15		7,75	13,33	3,57	24,65		30,30	49,31			8,8
Duiven	1	85	105	Yes	90	-5		125	125	85		20	3	23	23,25	45,95		21,96	47,62	10,12	79,70		45,95	79,70			19,7
Gilze-Rijen	1	55	80	Yes	65	-10		75	75	55		11	3	14	16,79	30,79		14,21	28,57	6,55	49,33		30,79	49,33			11
Gorinchem	1	40	75	Yes	60	-20		50	50	40		8,4	3	11	15,50	26,93		10,33	19,05	4,76	34,14		26,93	34,14			8,43
Huizen	1	60	135	Yes	120	-60		90	90	60		16	3	19	31,00	50,14		15,50	34,29	7,14	56,93		50,14	56,93			16,14
Katwijk	1	40	85	Yes	70	-30		40	40	40		8,4	3	11	18,08	29,47		10,33	15,24	4,76	30,33		29,47	30,33			8,39
Leiden	3	35	65	Yes	50	-15		30	90	105		7,4	3	10	12,92	23,32		9,04	11,43	4,17	24,64		69,95	73,91			22,2
Niewerkerk ad Ijssel	1	20	2	Yes	-13	33		20	20	20		3,5	3	6,5	-3,36	3,14		5,17	7,62	2,38	15,17		3,14	15,17			3,5
Nieuwkoop	1	60	120	Yes	105	-45		45	45	60		11	3	14	27,13	40,95		15,50	17,14	7,14	39,79		40,95	39,79			10,82
Nijmegen	1	90	125	Yes	110	-20		120	120	90		20	3	23	28,42	51,82		23,25	45,71	10,71	79,68		51,82	79,68			20,4
Oosterhout	1	50	90	Yes	75	-25		65	65	50		12	3	15	19,38	34,14		12,92	24,76	5,95	43,63		34,14	43,63			11,76
Poortugaal	1	45	55	Yes	40	5		22	22	45		2,7	3	5,7	10,33	16,02		11,63	8,38	5,36	25,36		16,02	25,36			2,69
Rome	1	55	140	Yes	125	-70		80	80	55		16	3	19	32,29	51,19		14,21	30,48	6,55	51,23		51,19	51,23			15,9
Rotterdam	8	20	35	Yes	20	0		7,5	60	160		0	3	3	5,17	8,17		5,17	2,86	2,38	10,40		65,33	83,24			0
Schiedam	2	15	30	Yes	15	0		6	12	30		2,3	3	5,3	3,88	9,18		3,88	2,29	1,79	7,95		18,35	15,89			4,6
Spijkenisse	1	20	65	Yes	50	-30		24	24	20		4,8	3	7,8	12,92	20,69		5,17	9,14	2,38	16,69		20,69	16,69			4,77
Ter Heijde	1	45	110	Yes	95	-50		30	30	45		7,3	3	10	24,54	34,87		11,63	11,43	5,36	28,41		34,87	28,41			7,33
Tilburg	1	60	65	Yes	50	10		90	90	60		13	3	16	12,92	28,82		15,50	34,29	7,14	56,93		28,82	56,93			12,9
Veenendaal	1	60	150	Yes	135	-75		90	90	60		16	3	19	34,88	53,78		15,50	34,29	7,14	56,93		53,78	56,93			15,9
Total	**38**							**aver**	**43**	**39**												**averag**	**24,65**	**31,31**	**6,66**	**aver**	**7,56**

Taxi																											
Origin	Count	TT car	TT PT	Via CS	TT CC	TT gain		distance	distance*count	TT car*count		Price PT to CS	Price CC	Costs PT	TT Costs	Total Costs PT		TT Costs	Car Costs	TT Cost driver	Total Costs K+R		Costs PT*count	Costs Car*count	Consumer Surplus		Price PT to CS*count
Den Haag	3	30	55	Ja	40	-10		23	69	90		5,8	3	8,8	10,33	19,14		7,75	50		57,75		57,43	173,3			17,43
Gouda	1	30	60	Ja	30	0		30	30	30		5	3	8	7,75	15,75		7,75	65		72,75		15,75	72,75			5
Rotterdam	6	20	35	Ja	20	0		7,5	45	120		0	3	3	5,17	8,17		5,17	20		25,17		49,00	151,0			0
Total	**10**							**aver**	**14**	**24**												**averag**	**12,22**	**39,7**	**27,48**	**aver**	**2,24**

Appendix 22: Yearly costs; investment annuity and operating costs

The annuity formula according to Lindström et al. (2015):

$$Annuity = Investment * \frac{i}{1-(1+i)^{-n}}$$

It is assumed that the track and stations have a lifetime of n = 30 years, for the vehicles the lifetime was set to 15 years. The interest rate has been set to 4.5% (same as the discount rates). With this formula, the annuity costs of the track can be estimated to 1.23 million, of the stations to 0.12 million and the vehicle annuities to 0.14 million per year. The total yearly investment costs are 1.49 million.

discount rate	4,5			
Investments	Costs	n	Annuity	
Track	20000000	30	1227831	
Stations	2000000	30	122783	
Vehicles	1500000	15	139671	
				1490285
Operational costs				
Maintenance track			200000	
Maintenance vehicles			75000	
Personel			280000	
Energy			41000	
				396000
			Total	**1886285**