Evaluation of International Train Service Alternatives

An in-depth case study for the Intercity Berlin

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Preface

The thesis investigates international long-distance passenger train transport. With this study, I am finalising the master programme Transport, Infrastructure and Logistics at Delft University of Technology. During the two-year program, I specialised in Design of Transport Systems and Networks, which soon became my passion.

For the great opportunity to graduate at Nederlandse Spoorwegen (NS), I would first like to thank Niels van Oort. As member of the committee and assistant professor at the university, he introduced me to Bart de Keizer from the timetabling department. Bart supervised my work with patience and enthusiasm. I am very thankful for his good advices and his trust in my work. Additional gratitude is addressed to Prof. Serge Hoogendoorn, Jan Anne Annema and Rob Goverde. With their scientific expertise in different fields and critical reflection on my work, they had a strong impact on this research.

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Dolores Brietzke,

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Summary

A comparison between mobility surveys of different European countries shows that trip distances, especially by train, have increased since 2000. This is in line with the latest observations on the Dutch-German train market, where in 2013 and 2014 record high passenger numbers were recorded. Additionally, the European Commission for Transport and Mobility supports train use for long-distance and cross-border trips, by the realisation of the Trans-European Network (Transport) project.

With the increasing trip distances on one hand, and the growth in train demand on the other hand, the demand side of train transportation changes. Additionally, operators state practical issues related to the supply side, such as the purchase of new rolling stock for the Intercity (IC) Berlin. Given the fact that railway infrastructure as well as rolling stock are built and financed for decades, the question arises on what the future services shall look like, in order to serve future demand.

However, in order to take such strategic decisions, in-depth market insights are required. Furthermore, a systematic approach is desired, to determine and test alternative train services (supply changes). A literature review on international passenger transport reveals several issues. The first relates to the low amount of available research in this field. Although cross-border train transport exists for more than a century, this topic is barely investigated in the past years. Most research on transportation is triggered by national problems. Regional or national authorities finance them and thus they are interested in solving local problems. The second issue relates to the available data on international long-distance trips. In most of the mobility surveys, daily trips are recorded. As long-distance trips appear less frequent, it is difficult to obtain representative samples of participants for statistical purposes. This is for instance the case in the Netherlands, where national long-distance trips are merely facilitated. Furthermore, international services provide low frequencies as they serve lower demand, than the national (short-distance) lines. Since international lines do not provide the majority of annual revenue, they are often considered as less important.

This study aims to reduce the scientific gap by providing insights into international passenger train transport. Hence, the research examines demand characteristics, in relation to supply characteristics, for long-distance, cross-border markets. With the insights on the current supply, decision-makers are able to detect weak-points of the service, such as long travel times. This knowledge helps to define alternative train services and improve the points. With the knowledge on demand characteristics, decision-makers are able to forecast the demand per alternative. Thus, this study addresses the following main research question:

How to evaluate international train services alternatives?

A generic framework is established to answer this research question. It is based on the planning hierarchy framework of Chang (2000), and is added, among others, with the evaluation step. Whether the framework is useful for international services, is tested with an in-depth case study of the IC Berlin. The practical case is applied on each step of the framework, provided in Figure 0-1.

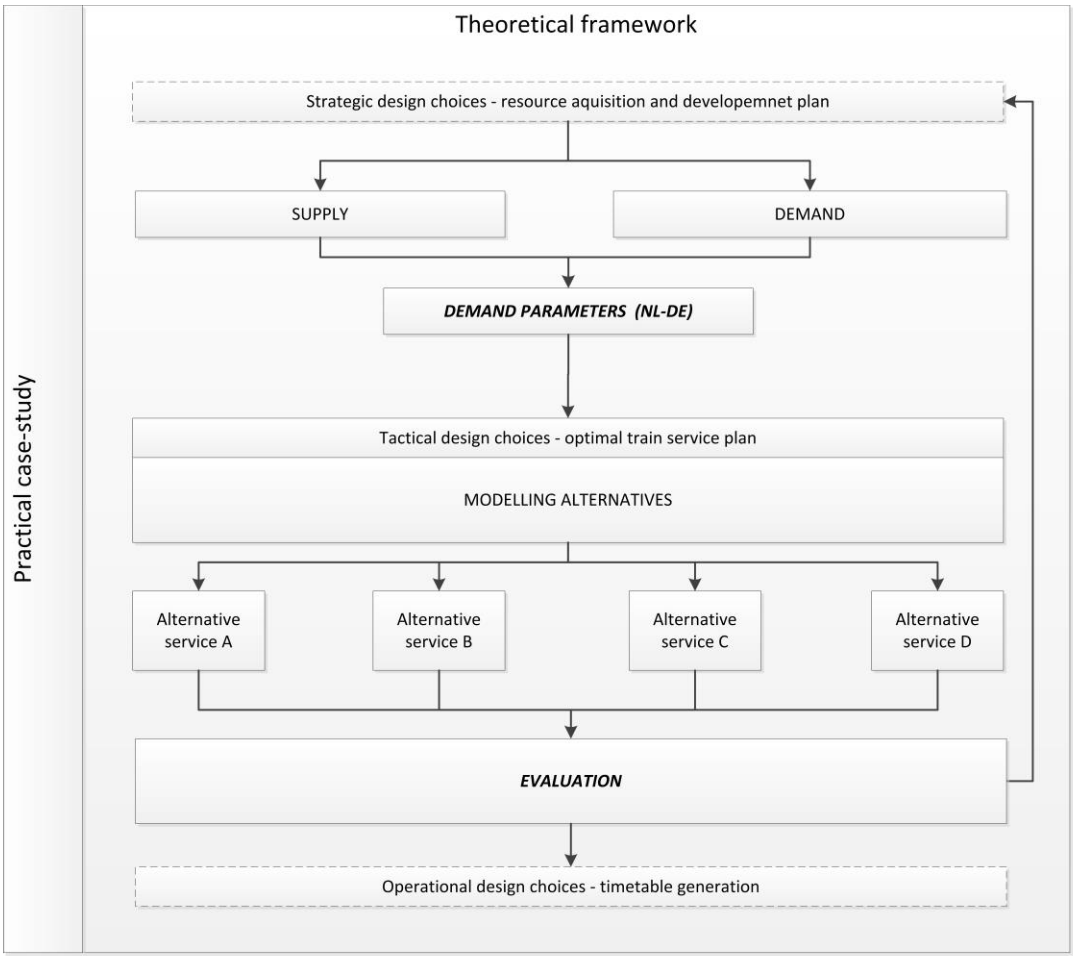

Figure 0-1: Evaluation framework for international train services.

Supply side

This framework step consists of four parts. First, international networks are defined. Afterwards, the Dutch-German network is investigated based on the definition given. As a third, the current long-distance services are closer examined. Since cross-border services operate in two countries, the number of stakeholders increases. Therefore, the fourth part provides a stakeholder analysis. From this framework step, the following insights over the Dutch-German market are gained:

The current international network between the Netherlands and Germany is composed by different network levels. The highest level (A) accomplishes long-distance or international connections. In literature, each level is characterised by the distance and transportation speed. For the international network level, this reveals in service distances of 300 km and speeds of about 160 km/h. However, these characteristics are only partly fulfilled for the Dutch-German network, and the operated international services. Considering the characteristic speed, such values are not realised due to the available infrastructure on one hand, and the technical differences between the countries on the other hand. In addition, international connections require more stakeholders as national services, which makes international transport additionally complex to provide.

Demand side

The demand side of the framework is investigated by gathering available information (NS studies) based on the current transport market. The conducted customer surveys show that the majority of Dutch passengers (75%) use the service for domestic trips. On the other hand, international passengers travel further distances, which generates higher revenues per passenger. Therefore, there are two important markets using the international service (national and international). Both groups can be further split into different trip purposes. Around 75 percent of the Dutch passengers and 90 percent of the international passengers (2014) use the IC Berlin for leisure trips.

In order to understand, how traveller groups with different trip purposes (leisure, commuting) react on adjustments in the future service; a train demand forecast model is required. In literature, different transport demand models are presented. However, due to the available data (aggregated ticket sale data), the application in practice (different European operators) and the indication in literature over train demand modelling, the elasticity model is chosen.

Demand parameters

The definition of demand parameters is an additional framework step, which incorporates the demand behaviour. In this study, international demand behaviour is investigated by defining demand elasticities. The values for long-distance, cross-border markets, such as Netherlands-Germany are obtained in two sub steps. First, relevant literature is reviewed. These outcomes reveal large ranges of demand elasticities. Second, experts in the field of train transport models are interviewed. Their answers provide better market insights on one hand, and reduce the ranges on the other hand.

The conducted literature review shows demand elasticities related to three service attributes: travel time, fare and frequency. These are the endogenous factors of a system, which influence demand. Furthermore, the found elasticities are distinguished between business trips (B), including commuting and non-business trips (NB), for all other trip purposes. As elasticities provide the percentage change in demand when a service attribute changes, they are strongly related to the demand and supply characteristics from which they are retrieved. The elasticities found in literature are derived from logit and advanced logit models, which are used to determine mode choice. Since competing modes are affected by changes of train service attributes, we investigate both types of elasticities, namely direct demand and cross-elasticities. However, due to the research scope, the focus lies on direct demand elasticities. The literature review shows that elasticities dependent on the study context, for example the type of model used, or investigated market (e.g.: business passengers in Canada). Although the literature is selected based on an assessment framework, especially established for this review, the elasticities presented in literature, provide wide ranges per service attribute and trip purpose.

In order to obtain more precise elasticity values for the Dutch-German train market, an interview is conducted with four experts on train demand modelling. In a semi-structure interview approach, each expert was asked on general insights of the market as well as their opinion on the elasticity ranges that were derived from literature.

Table 0-1: Resulting elasticities - train service attributes.

	Train		Air		Car	
Rail service attributes	Business (B)	Non-Business (NB)	Business (B)	Non-Business (NB)	Business (B)	Non-Business (NB)
Travel Time	**-1.0**	**-0.6**	0.3	0.1	0.3	0.1
Fares	**-0.5**	**-0.8**	0.2	0.2	0.2	0.2
Frequency	**+0.4**	**+0.2**	-0.1	-0.1	-0.1	-0.1

Table 0-1 summarises the resulting elasticities for the three service attributes, i.e. travel time, fare and frequency. Furthermore, the outcomes are split into business and non-business trip purposes as well as into competing modes, i.e. train, airplane and car. From this study, it is concluded that business train passengers are the most sensitive on travel time changes. Setting a value of one, results in an elastic demand. Hence, if travel time decreases by 10 percent, additional business passengers increase by 10 percent. Non-business passengers are the most sensitive on fare adjustments. Thus, with a fare reduction of 10 percent, additional leisure passengers (NB) are gained with 8 percent

From the literature review and expert interviews, it is revealed, that the determination of cross-elasticities is strongly related to the mode shares. Since the shares, as well as available modes vary for each origin-destination (OD) pair, we provide cross-elasticities for the OD-pair Amsterdam-Berlin.

Modelling alternatives

Based on the aforementioned knowledge on the supply side, alternative services for the IC Berlin are determined. With the insights gained on the demand and demand parameters, these alternatives are tested. Using the relevance tree, four different service alternatives for the IC Berlin are pointed out. The tree consists of a number of theoretical measures per alternative. These are subsequently translated into real adjustments of the current service. The first, the infrastructure alternative, suggests the realisation of new high-speed infrastructure between Amsterdam and Hannover. Calculation shows that for this scenario there is a decrease on travel time by 42 percent in comparison with the reference case. The rolling stock alternative results in a travel time reduction of 8 percent due to the introduction of interoperable locomotives and timetable adjustments. The network alternative reduces travel time with 10 percent by skipping 13 intermediate stops and running over a faster alternative route (Zwolle). Additionally the frequency is doubled (100%), which provides eventually a reduction in waiting time. In the revenue alternative, the international fare is reduced by 23 percent.

Table 0-2: Alternatives for the IC Berlin.

		Improvements (Amsterdam-Berlin)		
Alternative	Measure in reality	Travel time	Fare	Frequency
		[hours]	[€]	[hours]
Reference	-	6.3	65	0.5
Infrastructure	Dedicated high-speed line between Amsterdam and Hannover. *IMPROVEMENT*	3.7 *42%*		
Rolling stock	Multi current locomotive with maximum speed of 230 km/h. *IMPROVEMENT*	5.8 *8%*		
Network	IC Berlin over Zwolle (Hanzelijn). *IMPROVEMENT*	5.7 *10%*		1 *100%*
Revenue	Single ticket 50 €. *IMPROVEMENT*		50 *23%*	

In order to understand how passengers will react on each alternative service, a calculation tool is required. For this purpose, we use the NS internal Lijnvoeringsmodel (LVM). Since both national and international markets need to be modelled, we extended the tool. The LVM incorporates among others, the investigated direct and cross-elasticities. The actual goal of this tool is to provide an optimal service, given the supply and demand characteristics. However, since the German national demand is not provided, the model is primarily used to quantify the alternatives.

The calculations show the highest increase in passengers and passenger kilometres for the infrastructure alternative. As the travel time reduction of 42 percent shows the highest improvement of all four alternatives, the outcomes are reasonable. In contrast, the network alternative performs the worst. Although the alternative leads to a travel time reduction and improved service frequency, the reduction from 16 to three intermediate stops, passengers (kilometres) drop. Since the outcomes are being compared to the reference case, the results are negative. The network alternative shows the importance of the LVM or comparable calculation tools to model train service alternatives for different markets (national and international).

Table 0-3: Quantified alternatives - LVM.

Alternative	Service improvement	Passenger numbers	Passenger kilometres
Reference case	-	X	X
Infrastructure	Travel time: 42%	+ 70%	+ 40%
Rolling stock	Travel time: 8%	+ 10%	+ 10%
Network	Travel time: 10% Frequency: 100%	- 2%	- 44%
Revenue	Fare: 23%	+ 8%	+ 3%

Besides the passenger numbers, the LVM provides operational costs. However, the realisation of each alternative requires additional investment costs. In order to incorporate these and the interests of other stakeholders as passengers or authorities, a societal evaluation is required.

Societal evaluation

The social cost-benefit-analysis incorporates the direct, external and distribution effects. Regarding the direct effects, the costs and benefits for operators and passengers are determined. As for the external ones, there is a CO_2 reduction due to the reduction in airplane and car use. Lastly, for the distribution effects the costs and benefits are distributed over NS and the German operator Deutsche Bahn (DB).

The evaluation reveals, that the rolling stock alternative provides a positive net present value of 50 million, over a project time of 30 years and a discount factor of 5.5 percent. The benefit/cost ratio of 3.5 shows that the alternative performs beneficial (ratio>1). Although the infrastructure alternative provides the highest gains from a passenger perspective, the high operational and investment cost results in a negative net present value.

Conclusions

The main research question is answered as follows:

With the stepwise application of the presented framework, including the application of the investigated demand parameters, future international passenger train services can be modelled. These insights provide input for a societal evaluation. Based on the evaluation outcomes, decision-makers are supported to make strategic design choices. In case of an implementation, tactical and operational design choices are affected.

The conclusions from this study can be divided into three parts, namely framework related, case study related and general conclusions for the international train transport.

Conclusion - IC Berlin

Network - There are technical differences between the studied countries, for instance the used voltages or speed limitations. This makes international transport challenging.

Demand - The expected annual growth for the Dutch-German market is around 1 percent.

Barrier effects - For long-distance trips, the border represents no barrier. Thus, for the Dutch-German market cross-border effects can be neglected.

Conclusion – Methods

Framework – The theoretical framework presents six steps, which enable decision-makers to evaluate international service alternatives. Dependent on the available data and the exact case, framework steps might be excluded. However, for every international service, which is operated by more than one company, the access to all information is difficult. Specifically, the missing national demand information for the foreign country forces decision-makers frame assumptions.

LVM - The use of a calculation tool (as LVM) enables the user to quantify service alternatives. As both, the national and international market are affected by service adjustments, but behave in different ways, service adjustments need to be modelled.

Conclusion - International train transport

Stakeholders - There are more stakeholders affected by international, than national services (e.g. two operators, two infrastructure managers). This makes a complete evaluation of services difficult.

National vs. international markets - International train trips within Europe are comparable to national long-distance trips. The majority of long-distance passengers travels for leisure purposes.

Trip purpose – Both, national and international passengers use international services. The majority of long-distance trips are done for leisure purposes.

Elasticity – Leisure passengers are the most sensitive towards fare and travel time. In contrast, passengers that are travelling for business or commuting purposes perceive travel time more important than fare. The travel time elasticity increases with an increasing distance. Cross-elasticities depend on the available mode shares.

Recommendations

Finally, from this study some general recommendations are stated:

Framework – The presented framework is tested with one case study. In a following step, the framework is recommended to be applied for a number of services and countries. From these studies a cross-comparison can be conducted to strengthen the here provided insights.

Cross-elasticities – In this study, mode choice is modelled with cross-elasticities. This insight is mainly used for the later evaluation of externalities, or to be more specific, the determination of CO_2 reduction. However, in case decision-makers are interested in mode choice for long-distance trips, we recommend investigating mode shares for more OD-pairs.

Service attributes – This study investigates the effects of travel time, frequency and fare changes on demand, which are measurable service attributes. However, for further research, we recommended the investigation of soft factors, such as service reliability and comfort. It is assumed that certain travellers groups evaluate these attributes even higher than fare or time.

Alternative for the IC Berlin – Finally, the rolling stock alternative is recommended on condition that there is a reduction of travel time by 8 percent in comparison with the current situation.

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1 Introduction

Passenger train connections between the Netherlands and Germany exists since 1850. The first cross-border line was 40 kilometre long. In the 90s, with the increase in car ownership the trip kilometres per passengers increased. The work from Violland (2011) shows this, by analysing different European mobility surveys. The comparison indicates that time spent on transport and distances travelled grows constantly, although the number of trips is regressive. Schafer and Victor (2000) show in their study that the increase in travel distance goes along with the increase in speed, as the travel time budget is fixed. Thus, covering greater distances results in faster transport modes.

Especially on the Dutch-German train market, this trend is documented. In 2014, for the third time in row, a record in passenger numbers is booked. With a cumulative increase of 7 percent compared to the previous year, the demand for the Intercity Express (ICE) Amsterdam-Frankfurt, and Intercity (IC) Amsterdam-Berlin increased ("NiederlandeNet," 2015). According to the German operator Deutsche Bahn (DB), these passengers are partly diverting from the airplane. Especially on distances, which can be reached in less than four hours, the train outperforms the airplane.

Nearly 90 percent of the international train passengers are travelling for leisure. Although in 2006 the Germans preferred the airplane above the train, when travelling to a neighbouring country, this mode choice was contrary for the trips to the Netherlands. Here the majority of passenger chose for the train (Statistisches Bundesamt, 2006).

The German, as well as Dutch market are dominated by the car mode, with a total share of 75 percent. Since the 50s, the car kilometre per capita and day increase more than by any other mode (Scheiner, 2010). However, since the last two decades the distances travelled by car remained unchanged, whereas the use of public transport, and mainly the train use increased (Violland, 2011).

1.1 Problem Statement

With an increasing demand in trip distances on one hand, and the continuous increase in train demand on the other hand, questions about the future train service are raised. For the train service between Groningen and Bremen (Wunderline) for instance, new studies are started to investigate the possibilities for an improved train service. For the IC Berlin, NS requires new rolling stock from upon 2024. However, given the fact that railway infrastructure as well as rolling stock are build and financed for decades, the question on future services is extended by the question of profitability.

Similar to every commercial company, train service operators seek to run a beneficial business. This is accomplished, if the supply of service meets the demand on the market. In case demand is low, for example in regional areas, authorities ensure public transport by subsidising the services. This enables a spread land use (job and house market) over the country. In both cases different attributes of the supply side can be adjusted, which will eventually lead to a change in demand. With attributes of the supply side for instance fare, travel time, or other service related specifications are meant.

In order for operators to achieve their goal of providing a beneficial service, they need to meet the passenger objectives, as for instance lower travel times. In addition to the passengers, authorities play a role. With their increasing interest in low-emission-transport on one hand and the improvement of regional economy, they support financially transport projects as the Wunderline (Provincie Groningen, 2015), in cases they increase social.

In order to do so, the current Dutch-German market, as well as demand characteristics needs to be known. One way is to retrieve them is from national travel survey. However, as the market requires insight into long-distance and cross-border trips, available data is limited. Usual transport surveys account for daily trips. As long-distance trips appear less frequent, it is difficult to obtain representative samples of participants for statistical purposes. This is the case in the Netherlands for instance, where national long-distance trips are merely facilitated (Frei, Kuhnimhof, & Axhausen, 2010).

Another way of determining transport demand characteristics is to review literature. However, most research on transportation is triggered by national problems as congestion or economic developments of certain regions. These projects refer to the national welfare and hence stop at the border. Furthermore, the regional or national authorities often finance these projects. With the money they are interested in solutions on national level, which holds mainly for short distance trips and is the majority if trips made (Goeverden, 2007). Hence, in literature international transport projects are merely represented for conventional train lines. In conclusion, demand parameters for the Dutch-German market are missing. This is different to investigations considering the implementation of high-speed lines.

From the points mentioned, three problems are stated:

- The train market faces changes in the future, which requires service adjustments.
- Statistical data for the Dutch-German passenger transport market is missing.
- Literature on demand characteristics for international and long-distance train usage is limited.

1.2 Research objective and questions

Derived from the problem statement, the challenges for international passenger transport are specified. The difficulties of international transport are especially on long-distance connections underreported. An example, which incorporates these challenges, is the IC Berlin. With the need to adjust the current service in the coming years, operators as well as national and international passengers will be affected. In order for the here conducted study to meet the earlier mentioned problems, as increasing demand or the lack of knowledge on international connections, the research aims to…

…determine a service alternative for the passenger train connection Amsterdam-Berlin from upon 2024, which is at least cost-covering.

In case the full market insights are given, as for example for national services, the required alternatives should provide a profitable performance. That implies that the benefits exceed the costs. However, since there are multiple operators, the determination of all benefits is complicated for international services. Hence, in order to bridge the missing financial insights of the German market (benefits), the research goal addresses cost-covering alternatives for the IC Berlin. With this minimum requirement (cost-covering), and the incorporation of all appearing costs, we ensure that the found alternatives perform eventually profitable.

Thus, this research objective covers a practical as well as theoretical perspective. The *practical* notion of this research goal considers the determination of various alternatives for a long-distance, cross-border, passenger train connection between two European cities. However, in order to generate cost-covering alternatives, the demand characteristics of the Dutch-German transport market needs to be known. With a limited number of studies on international markets on one hand, and the increasing demand for long-distance travel on the other hand, the *scientific* objective of this research is stated.

The research objective will be achieved by answering the following main research question:

How to evaluate international train service alternatives?

Related to the main research question several sub questions are stated. The sub questions 2 and 3 relate to different aspects. Therefore, the questions are split into part a, part b and will be answered sequentially throughout the report. Insights gained from each sub question contributes to the answer of the main research question. The sub questions are stated as follows:

(1) What defines international passenger train transport networks and what are the characteristics of the Dutch-German network?

(2) Which demand parameters are required to model demand behaviour for the Dutch-German market?

   a. How can (train) demand be modelled?
   b. What are the demand parameters for the Dutch-German market?

(3) How can train service alternatives be determined?

   a. What are the alternatives for the IC Berlin?
   b. How can these alternatives be tested?
   c. Which service alternative provides the highest demand?

(4) What are the effects of a future service between Amsterdam and Berlin?

1.3 Scientific and societal contribution

Although different studies predict increasing passenger kilometres in the future, little study is conducted on the solution of this trend. Researchers as Balcombe (2004), Goeverden (2007), Scheiner (2010), or Violland (2011), describe in their studies future trends in transportation. Other studies show mathematical solutions to calculate mode choice in a more precise way, than for instance classical logit models do (Bhat, 1995; Cascetta & Coppola, 2014; Koppelman & Wen, 2000; Mandel, Gaudry, & Rothengatter, 1997). However, according to our knowledge, there is little research conducted which elaborates on the approach to determine and evaluate future service alternatives.

The scientific contribution of this study seeks to reduce this gap. With the establishment of a theoretical framework to take design decisions, users are able to determine and test train service alternatives. Furthermore, in order to evaluate these train service alternatives, the study investigates demand behaviour. Since little research is conducted on demand prediction for international connections, decision-makers are unable to forecast the effects (in terms of passenger numbers) of adjusted train services. Thus, this research provides insights into passenger demand behaviour for international, long-distance train markets.

The societal contribution of the study relates to the interest of the different parties involved. With the insight on demand characteristics for the Dutch-German market on one hand, and a testing tool for alternative services on the other hand, operators achieve a better insight into the market possibilities. In case a better alternative is found and implemented, the consumer as well as the producer surplus increases.

1.4 Scope

The research seeks to determine, and eventually choose alternatives for the IC Berlin from upon 2024. After this period, new rolling stock needs to be purchased. In literature and practise, the acquisition of new rolling stock and other high investments are decided on a strategic level. This is the highest level in a planning hierarchy for passenger transport and incorporates long-term decisions over periods longer ten years. The second level refers to the mid-term planning strategy, and incorporates the tactical decisions, for periods from one until ten years. Decisions important for short-term planning are taken on the operational level. The last one incorporates vehicle and personnel scheduling, as well as train monitoring and controlling. As this study answers the research question on a conceptual and hence macroscopic level, the presented study does not incorporate operational decisions. By excluding this perspective, constraints resulting from vehicle, personnel or infrastructure limitations are unconsidered.

As operational limitations are neglected, the solution area is wider than often found among practitioners. Operators and other decision-makers, tend to find practical solutions, which are close to the known service. However, this study is meant to enlighten the number of possibilities, by giving a broad insight into distinctive alternatives. These so called "extreme" alternatives as high-speed, or direct connections (less intermediate stops), are thus possible within this study.

Nevertheless, the extreme alternatives do not involve alternative modes. The opportunity for rail service providers to operate other means of transport are excluded from this investigation.

Finally, the research goal refers to "…cost-covering operation…", and states the minimum economic performance of an alternative train service. Alternatives, which perform considerably more profitable, are preferred. Nevertheless, due to the lack of financial insights of the Deutsche Bahn, the complete financial evaluation per alternative cannot be given.

1.5 Research design

The research consists of two steps. In order for decision-makers to evaluate alternatives for international services, a generic framework is established. It is based on the planning hierarchy framework from Chang (2000). However, in order to provide an answer to the research question, among others, the evaluation step is added. The entire framework is explained in sub section 1.5.1. In order to understand, whether this framework is useful for this type of evaluation, an in-depth case study is conducted. Each step within the framework is tested immediately by applying the case.

Hence, the research consist of two steps:

1. **Theoretical framework**
2. **Practical case**

The section ends with the research outline, which contains a list of methodologies used per chapter.

1.5.1 Theoretical framework

The theoretical framework is based on the three levels of design choices (strategic, tactical and operational), classified by Anthony (1965). Chang (2000) uses these three levels to establish a "planning hierarchy for passenger train services"[1]. In his work, the author presents a multiobjective model to cope with the optimal allocation of resources to establish a train service. In order to serve the passenger as well as operator objective (multiobjective), the work focuses on three service attributes, namely the number of intermediate stops, frequency and number of vehicles required. With this predefinition of service attributes, the framework is specified to a case in Taiwan, the author refers to. However, for international services, the service attributes might differ.

Hence, in order to answer the main research question, the theoretical framework needs to be modified. Figure 1-2 illustrates the resulting framework.

[1] The original framework can be found in (Chang et al., 2000), p. 94.

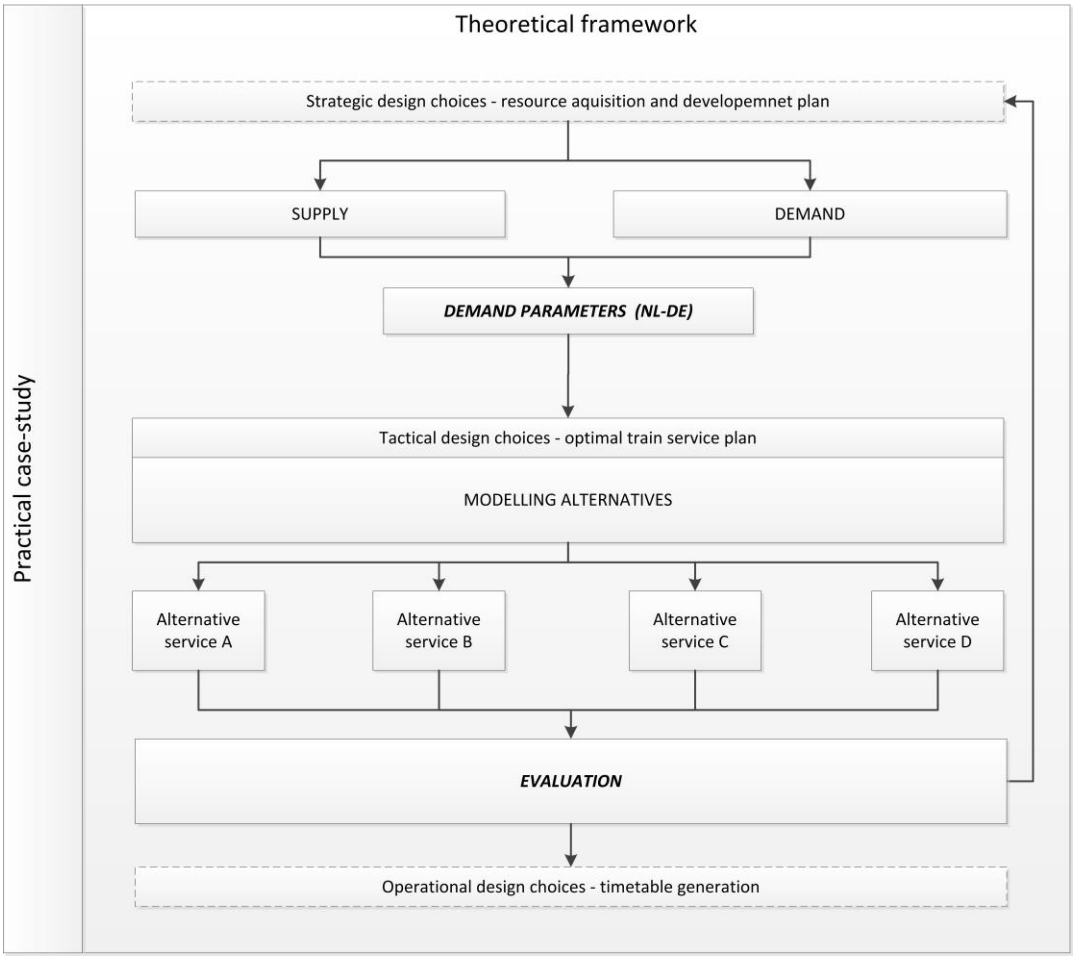


Figure 1-1: Modified framework after Chang (2000).

On the highest level, strategic decisions are taken as for instance the acquisition of new rolling stock. These decisions influence the supply and demand side within the transport market. The supply side incorporates the network and service related aspects, as the available infrastructure, capacity of rolling stock, prices, etc. For the demand side, information is required related to passenger numbers. In order to model international services, the demand behaviour needs to be known. In the original model established by Chang (2000), the demand depends on the travel time only. This is an assumption made by the author to build his model. Other influencing factors, might be related to the mode choice and are sated by Ortúzar & Willumsen (2011). Hence, in order to use the framework in a more generic way, an additional block is introduced to the framework, the demand parameters.

Demand and supply serve as input for the tactical decisions. On this level, the service plan is established which incorporates different service attributes as frequency, travel time, etc. Each combination of these service attributes, results in an alternative for the current service, symbolised by the letters A, B, C, and D.

In a final step, the alternatives are evaluated. In comparison to the original framework, this step is new and implemented in order to answer the main research question. The outcomes of the evaluation might require new investments and are therefore linked (arrow) to the strategic level. Both, the demand parameters and the evaluation step are added to the framework, and hence highlighted (bolt and italic). As the strategic and operational level are influenced, but not investigated in detail, they are illustrated in dashed boxes. In capital letters the five framework steps are presented, which are important for the structure of this report and thus used in the outline (section 1.5.3).

With the application of a case study, the theoretical framework is tested. This is indicated in the figure with a vertical chart (left).

1.5.2 Practical case

Chang (2000) established the theoretical framework for the high-speed service in Taiwan. In order to use this framework for international passenger connections, the framework is modified as explained in the previous section. In order to test the usefulness of this framework in practice, an in-depth case study is conducted. The case of the intercity Berlin shows societal as well as scientific relevance.

From a societal point of view, the case of the intercity Berlin shows three interesting aspects. First, both operators, NS and DB need to take a strategic decision regarding the rolling stock. From 2024, the current vehicles need to be replaced. Second, the line accomplishes a distance of more than 600 kilometres. With the low operational speed and the high number of intermediate stops, changes will lead to relatively strong effects. In contrast to a short line with little intermediate stops. There service changes are assumed to have a smaller impact. Finally, the intercity Berlin has an important national and international function. This implies a complex balance between both markets.

- Rolling stock needs to be replaced until 2024
- Low operational speed, and high number of intermediate stops
- Important for domestic and international passengers

The most obvious is the need from both operators, NS and DB, to decide on new rolling stock from upon 2024. However, with this investment, new chances for an improved service appear. In addition, the current service operates on a low average speed, with many intermediate stops. Hence, for an intercity service more adjustments are possible than considering a high-speed connection, which makes the solution area big. Finally, the IC Berlin has an important national function in addition to the international function. This implies, a complex balance between national and international use.

From a scientific perspective, the case is especially interesting as recent investigations are often based on high-speed services. For regular intercity connections, which are a majority in the network, little literature is published the last decades. Hence, the intercity Berlin represents a case, which contributes to the following gabs:

- Intercity study
- Long-distance study
- Cross-border (international) study

1.5.3 Methodologies and outline

The theoretical framework consists of five main building blocks, as illustrated in Figure 1-2 in capital letters. These blocks are supply, demand, demand parameters, modelling alternatives and the evaluation step. Instead of elaborating on each block in a theoretical way, the case study is applied. In this way, the framework is tested on whether it can be applied in practice. This report is structured according to these blocks. Sequentially from top-left to downright, the framework is tested. The research outline is illustrated in the following Figure 1-2.

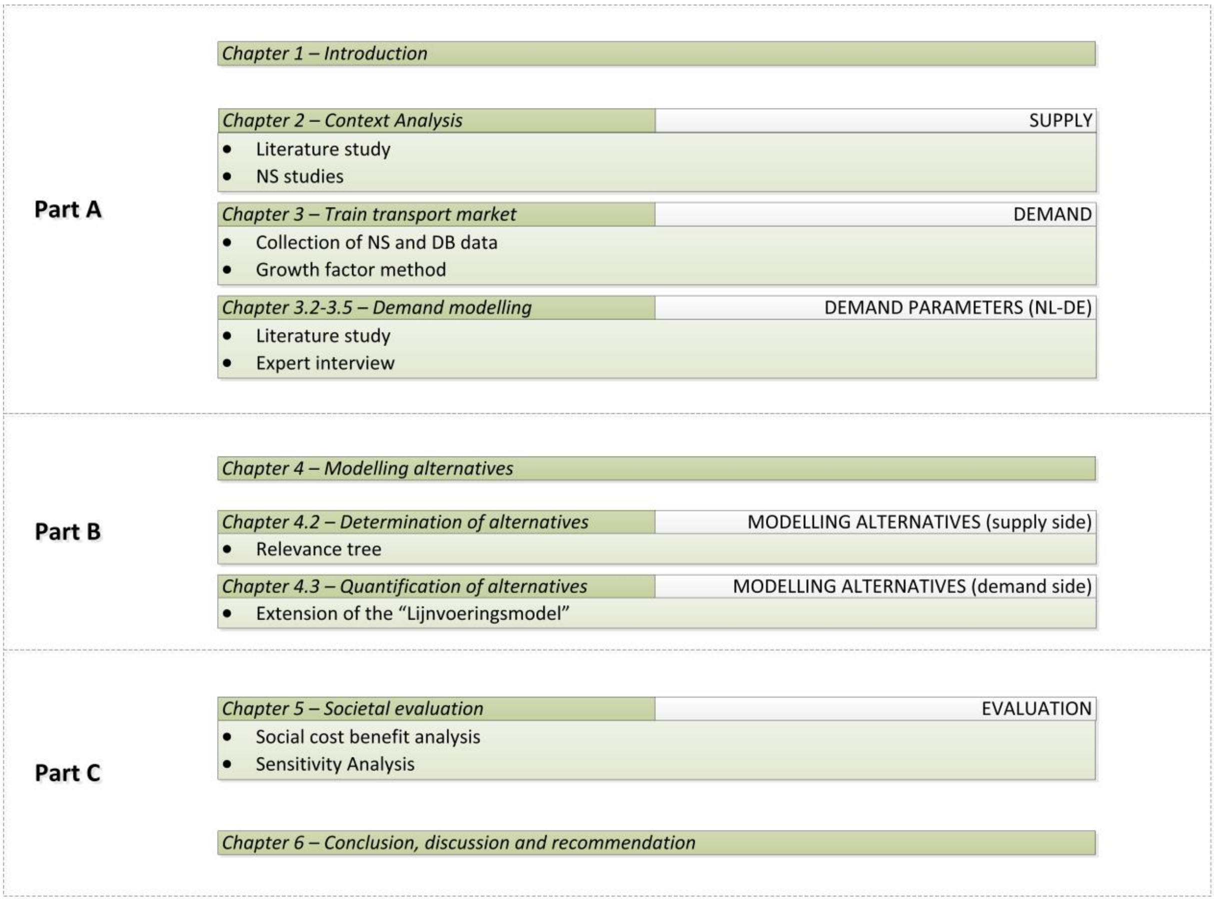


Figure 1-2: Research outline.

In white boxes, the building blocks of the framework are presented, which are in line with chapters or sections of this report. As the blocks differ, the methodologies used per step vary. All methodologies are listed with bullet points. The exact explanation is given in the beginning of each chapter. The entire report is split into three parts (A, B, C). Every part serves as an input for the following part.

Part A

2 Network and service analysis

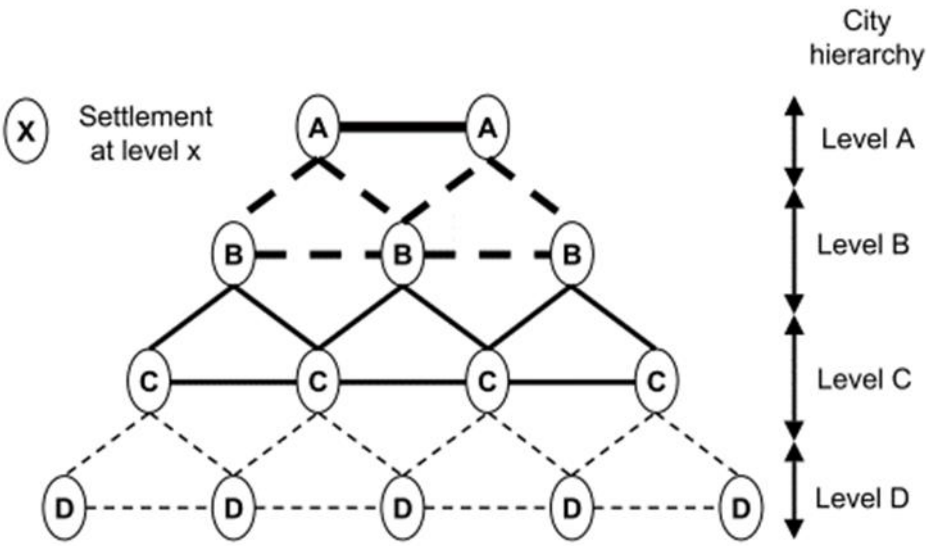
This chapter starts with a general description of networks. In literature, they are characterised by network levels, which are provided in the first sub section. The international network is classified among others with long-distance connections. However, as presented in section 2.1.2, the term "long-distance" is defined differently throughout literature. In the second section, the network levels for the Dutch-German network are illustrated. Furthermore, the technical differences are presented. The network is operated with two different service types, which are presented in the third section. With a stakeholder analysis, the main actors are presented and their influence explained. The chapter end with the answer to the first sub research question.

2.1 International network characteristics

2.1.1 Network levels

In order to define the term "international network", the work form Nes (2000) is closer examined. In his work on "Design of multimodal transport networks: A hierarchical approach", the author explains that spatial structure determines the level of public transport. He investigates network attributes as distances between lines (line spacing) and distances between stops (stop spacing), to determine the difference between networks. Moreover, he classifies public transport networks by determining different speeds characteristic.

The work distinguishes between urban (radial) and interurban (triangular) networks designs. The latter is divided in four levels. Starting at the lowest level for short distances, the network levels increase stepwise. Due to the different characteristics, the levels are operated by various services, which vary among countries. Due to the scope of this research, the corresponding service per network level is presented solely for Netherlands and Germany. The entire pyramid is illustrated in Figure 2-1.



NL	DE
IC; ICE; Thalys; Eurostar	IC; ICE; TGV; etc.
Intercity	Regio-Bahn (RE)
Sprinter	
	S-Bahn, U-Bahn, etc.

Figure 2-1: Modified road network structure according to Schoenharting & Pischner (1983) (Nes, 2002).

On the lowest level of the pyramid, level D, small settlements are served. The network can be translated to the local or agglomeration network. This network is specified by a high frequency, and low travel times (average speed 30km/h), and a high stop density. On this network level distances below 25 km are served. Level C is located on a regional level and comprises distances up to 40 km. Both levels C and D are served in the Netherlands by the Sprinter. In Germany the type of service depends on the region. Short distances in big cities are operated with S-Bahn, U-Bahn and comparable services. However, for local short distances in less populated areas, this function is served by busses. In general level C and D are relevant for connections of towns and villages.

The next higher level B connects regions and thus accounts for distances up to 100 km. In the Netherlands this service is provided by intercity services. However, the distinction between these services is not fixed. Intercity services do also operate on shorter distances, whereas Sprinters also serve longer distances. However, due to the number of intermediate stops, which are higher for the Sprinter service, the intercity service is operated faster (100 km/h) and hence considered as higher level transport. In Germany, this service is provided by so call regional trains (Regio-Bahn).

The highest network level A, serves distances of 300 km and more. Due to the geographical size of the country, the Netherlands provides barely national connections on this level[2]. However, with connections to Germany, as well as France, Belgium and the UK, NS services the international network. This network level is operated by services as the Thalys, Eurostar or Intercity Express (ICE). Germany serves the national as well as international long-distances with the ICE, TGV and others. It is highlighted that in literature these distance are related to speeds of 160 km/h and more.

As explained with the example of the Sprinter and Intercity service in the Netherlands, the services are not clearly separated. However. The different levels of networks indicate an approximation, which service on the supply side is the most appropriate. Nevertheless, also on the international level there are exceptions. For the connections between Amsterdam and Berlin for instance an intercity service is provided.

The train connections between the Netherlands and Germany cover distances between 20 km and 650 km and will be presented in section 2.2. Given these distances, the network between both counties covers different spatial levels (Level D – Level A).

2.1.2 Long-distance trips

As the international network level covers the longest distances, trips on these network are translated to long-distance trips. In this way the lack in literature on international trip characteristics is compensated with the trip characteristics defined for long-distance trips. However, in literature the definition for long-distance trips varies strongly. In the German KontiFern study from 1980 these trips are described as trips between 50 km and 100 km. The Kite survey (2002) defines these trips between 75 km for Switzerland, Czech Republic and Portugal, and 100 km if considering long-distance trips in Germany. However, Axhausen (2010) quotes the same survey, but makes no difference between the countries and describes all trips with 100 km distance. Furthermore, the distances can be given in route length (available roads) or crow-fly length. Another categorization refers to overnight-stays, which makes a unique definition of long-distance trips difficult (Frei et al., 2010).

2.2 Network Netherlands-Germany

2.2.1 Railway network

The first train cross-border connection between the Netherlands and a neighbouring country was the Aachen-Maastricht line built in 1853. This was a 40 kilometre long track extension of the German network. Nowadays there are in total seven cross-border connections between both countries (see Appendix A). The border-crossing services differ in the location they cross the border, the operating company and the cities they connect. In the following the connections are split based on the network level B, which covers 100 to 300 kilometres and network level A, for connections longer 300 kilometres.

<u>Network level B</u>

This type of network level connects the east part of the Netherlands with the western part of Germany and is illustrated in Figure 2-2.

[2] The line Alkmaar-Maastricht and Groningen-Vlissingen are the longest lines with almost 400 km (NS).

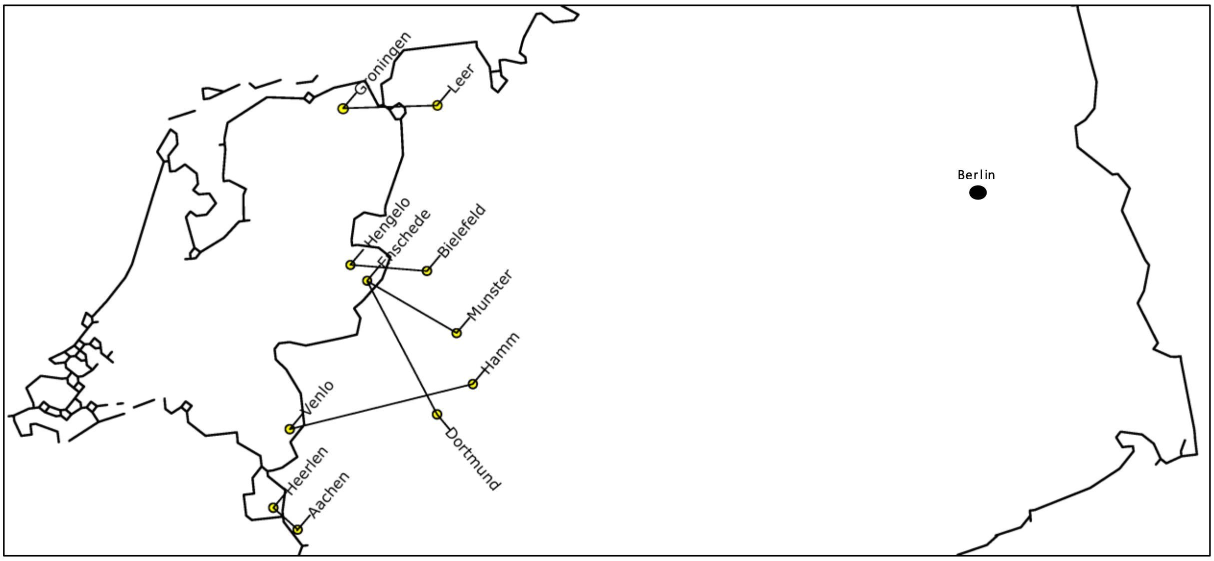


Figure 2-2: Network level B connections (own figure).

On the northern part of both countries operates Arriva line 20100 between Groningen and Leer. Enschede more southwards, is linked to Münster and has a south connection to Dortmund. The last two of five regional border services connect the southern part of the Netherlands as Venlo or Heerlen, with Hamm and Aachen respectively. The two longest regional lines (~140 km) across the border are the connection between Enschede and Dortmund with a travel time of 2:11 hours and the connection Venlo-Hamm that takes 2:29 hours.

In general, borders represent a travel demand reducing effect in comparison to domestic trips. (Rietveld, 2012) reasons these effects with preferences, institutions, information and others, which differ per country and thus reveal in a barriers for cross-border commuting. (Knowles & Matthiessen, 2009) describe international borders as cultural, political and economic barriers, which lead to inaccurate traffic predictions for international road and rail projects. Based on this insight a decreasing demand for the regional cross-border lines is expected.

However, the transport ministry of Nordrhein-Westfalen Germany, forecasts for the southern border connections an increasing passenger and freight transport demand in 2025. The connections to Heerlen and Venlo are indicated as bottlenecks with capacity demands between 85 and more than 110 percent. As a reason the ministry indicates increasing fuel prices on one hand and an increasing economy of border regions on the other hand. Also the Dutch government estimates for the border regions Noord-Nederland, Noord-Brabant and Limburg, an increasing demand on housing, which reveals, according to the circle from Wegener, to an increase in transport demand ("Gebiedsontwikkeling per regio | Ruimtelijke ordening en gebiedsontwikkeling | Rijksoverheid.nl," n.d.).

For the region Noord-Twente (east Netherlands), a decrease in population is forecasted. Nevertheless, this does not imply that border traffic is less stimulated. In contrast, with a new timetable as well as interoperable rolling stock (explanation in section 2.2.2), the Eurobahn offers from 2017 an improved service between Hengelo and Bielefeld. The changed service seeks to improve the traveller experience on one hand and attract more passengers on the other hand. The so called Wiehengebirgsbahn passes in total four intermediate stations of the IC Berlin[3]. In addition to this project, the connection between Groningen and Bremen is investigated. With the financial support of the European commission, the costs and benefits of the "Wunderline" are investigated. The region Groningen seeks to improve the attractiveness of Groningen for students and commuters by reducing the travel time from currently three to less than two hours.

Network level A

[3] Bad Bentheim, Rheine, Osnabrück, Bünde (Westfalen).

Historically there used to be many lines between the Netherlands, Germany and other European countries. In the 70ies the NS provided direct connections to Italy, Austria, Switzerland, France, the UK and countries in between. Frequencies of three to eight times per hour were offered. To German destinations as Hamburg, Munich and others, frequencies of at least ones per hour were provided. There were special services as car-sleep-trains for the summer season, bringing passengers to from the Hoek van Holland to France, Italy or other destinations. The same holds for the winter season, where winter destinations were served. A rather special service was provided to the Lourdes (France), which was advertised as pilgrimages destination. These lines served mainly leisure purposes. However, back then a high demand was stated by the military, as soldiers used the train to travel between their bases and home countries. Furthermore, 1st class train trips were considered as luxury mean of travel for both business and private passengers. The luggage, freight and mail was transported separately on dedicated freight infrastructure. Due to their service characteristics "summer/winter leisure", the lines started at different Dutch stations. These were Hoek van Holland, Den Haag, Den Bosch or Amsterdam. One of the biggest differences compared to the present day, is the reduced competition to other modes as for instance air transport.

Nowadays, the long-distance service between the Netherlands and Germany is reduced to two lines, which are presented in Figure 2-3.

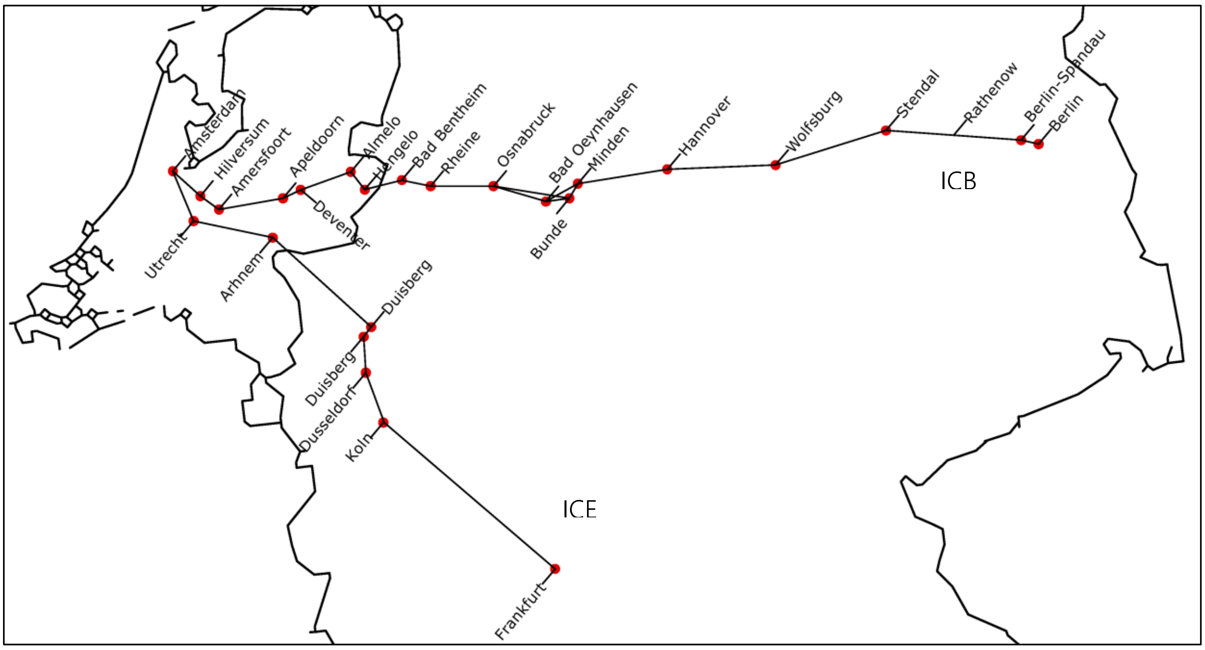


Figure 2-3: Network level A connections (own figure).

The first connects Amsterdam with Berlin on a straight west-east connection. Due to its speed and type of service it is called intercity Berlin (ICB). The second connects Amsterdam with Frankfurt am Main over a south-east connection and offers an intercity express service (ICE). In addition to the reduced number of lines also the number of services declined from ones per hour, to ones per two hours. The big national railway operators NS and DB offer the long-distance connections between the Netherlands and Germany jointly.

Besides the connection of the two capitals, the ICB serves intermediate stops as Osnabruck and Hannover. With inhabitants of more than 160.000, 500.000, and stations to facilitate low as well as high-speed services, these stops are considered as important (transfer) nodes in the network. However, links to other big cities, as for instance Hamburg, are missing. Passengers heading towards this destination need to transfer at Osnabruck. The ICE to Frankfurt runs through the Ruhrgebiet and passes there big cities as Köln or Duisburg. Other cities within the Ruhrgebiet as Essen, Bonn or Dortmund with up to 500.000 inhabitants, can be reached by transferring at Köln or Duisburg. Cities in the middle and south of Germany have no direct rail service to the Netherlands during the day. During the night, the City Night Lines service offers a direct connection to Munich and Zurich. These two lines serve some additional stations ones per day. Until December 2014 existed a direct

City Night Line service to Praha, over Berlin. However, with the timetable 2015, passengers to the east of Europe as Poland or the Czech Republic need to transfer at Oberhausen.

Both presented long-distance connections start at Amsterdam. Intermediate stops are Utrecht and Arnhem before crossing the border at Oberhausen. The ICB is here an exception. As the only line runs this long-distance service over Bad Bentheim.

2.2.2 Technical settings

Historically, railway transportation was developed on a national level. Different manufactures specified the rail transport network as it is found today. However, these country specifications are incompatible with each other. Crossing the border faces thus specific challenges. Examples are the differences in energy supply, or track gauge[4], which are still found in European countries as Spain or Lithuania (European Commission, 2013). In addition, the safety system used in each country, might hinder cross-border traffic. The European Commission describes these problems for Transport and Mobility with the lack of interoperability.

Although there are in total seven (from 2017 eight) connections between the Netherlands and Germany, the differences in network characteristics still exist. In this section technical characteristics and differences of both networks as well as used rolling stock are given.

Network

In 2006, the Dutch network was the most occupied railway network in Europe. The main institution for Dutch statistic (CBS), measured the occupancy of the European and especially Dutch railway network. In their study they formed a ration between the number of passenger kilometres (pax km), and the total network length. The study reveals, that the Netherlands realised in 2006, around 2.5 million pax km per rail kilometre. Germany in contrast, realised around one million passenger kilometre per rail kilometre. Two points mainly reason the high density. First, the high amount of people travelling by train, and second the low amount of available rail network kilometres. With 17 kilometre per 100,000 inhabitants, the Netherlands provides the lowest amount on network. The European average is 44 km per 100,000 inhabitants. The German network density is around this average.

Besides the network density of both countries, the voltage on the catenary represents a major difference. Due to historical developments of the railway industry within each country, different voltages supply the railway network. In the Netherlands supply is provided by a 1.5 kilo volt, direct current system (ProRail, 2014). However, in Germany the energy supply is ensured by a 15 kilovolt system and is thus higher than in the Netherlands. Furthermore, the German system provides single-phase current voltages. However, not all railway tracks provide electrification. Of the 3000 km network in the Netherlands, 25 percent have no electrification (CBS, 2014), and need to be operated with diesel locomotives. In Germany the share of electrified tracks is only 60 percent (Stuttgarter Zeitung, 2012).

Another difference is presented by the safety and cab signalling systems used in each country. The Netherlands uses the automated train protection system (ATB), whereas in Germany Indusi (Punktförmige Zugbeeinflussung Punktfoerminge: PZB) or LZB (Linienzugbeeinflussung) is used. In Table 2-1, network characteristics are listed, which differ in both countries and require additional in-vehicle solutions in order to serve both countries.

Table 2-1: Network differences.

	Netherlands	Germany
Voltage	1.5 kV (Direct current - DC)	15 kV, (Single phase current)
Safety system	ATP	PZB, LZB

International service (rolling stock)

[4] Spacing between rails on the railway track.

Two types of services, namely the ICE Frankfurt and IC Berlin (see 2.2.1) compose the network level A. The services mainly differ in their rolling stock. Other characteristics, as number of intermediate stops or frequency, will be explained in the case study (2.3).

Among passenger trains, we distinguish between locomotive hauled wagons and a multiple unit train (electrical multiple unit = EMU). Due to the history of steam trains, which proved to be the most efficient with increasing size, the classical train is considered as a set of locomotive and wagons being hauled. However, nowadays the trend goes towards multiunit trains, where the traction force is not build into the front unit only, but integrated over the entire length of the train. The latter train type appears to be superior due to advantages as the higher utilisation of the train length. As passengers are also facilitated in the front and end car, almost 20 percent more passengers are can be transported over the same train length. Furthermore, with the distributed driving axles, the acceleration capability increases as well as higher slopes are overcome. With the distribution of drive force over the entire train, are higher speeds possible (Forschungs-Informations-System (FIS), 2011).

2.3 Services between the Netherlands and Germany

In general, there are two long-distance connection between both countries, namely the ICE towards Frankfurt and the IC Berlin. Additionally to the first mentioned, there is an ICE service towards Basel (CH) ones per day and direction. However, due to the low frequency, the service is combined with the line towards Frankfurt. In the following, both services are briefly described. However, since the IC Berlin is used as the case study of this research, this service is explained more extensively.

ICE Frankfurt

The ICE Frankfurt is operated ones in two hours and serves thus with a frequency of six times per day and direction, the two cities Amsterdam and Frankfurt. The connection serves in total nine stops, spread over 405 kilometres. Six of these stops are located on the German, three on the Dutch side. The line passes the border in Emmerich. The used rolling stock is an electrified multiple unit (EMU), which is the fastest of its type. With maximum speeds of 330 km/h, the ICE is built for high-speed connections. Special about this type, is the interoperability for France, Belgium, Germany and the Netherlands.

IC Berlin

The reason to choose the IC Berlin as case study is twofold. First, the practical problem for the both operators, to renew their current rolling stock over less than 10 years. Second, the IC Berlin fulfils two functions. With, in total 16 intermediate stops and a maximum speed of 200 km/h, the service operates as an interregional (national) train in both countries. However, by connecting both IC services, an international connection reveals. Due to the difference in voltage supply in both countries - 1.5kV (direct current voltage) in the Netherlands and 15kV (single phase current) in Germany - a standard Dutch or German locomotive is unable to drive the entire route. This problem is solved by changing the locomotive at the border. The wagons are thus dragged towards the border, where the national locomotive is decoupled and the foreign locomotive attached. The report refers to this situation with “locomotive change”.

Given this situation, international passengers face a waiting time of around 10 minutes in Bad Bentheim, the last station in Germany. Although the maximum speed of 200 km/h is rather high compared to 140-160 km/h (Dutch rolling stock speeds), the operational speed over the entire line is approximately 105 km/h (630km/6.2h). This low realised operational speed is reasoned with the number of intermediate stops on one hand, and its IC status on the other hand. The high number of intermediate stops, may cause delays when dwell times are exceeded. If delay occurs at stations, trains of higher hierarchy as the ICE are privileged. At stations as Hannover, which is an important transfer node in the German network, this situation appears frequent. Although this station is located at the beginning of the line, the delay often propagates until the border. In order to avoid delays at the final destination and complicate turnaround procedures, the timetable incorporates running time supplements, and thus reduces the average speed. The running time supplement will be explained later in this report section 4.2.4

The entire service (in both countries) is accomplished with 12 trainsets. One trainset is composed by 9 wagons and one locomotive at the head. The wagons are independent from voltage differences and can be thus inserted in both countries. With the locomotive change, also personnel changes, which is composed by the train driver and two conductors.

Furthermore, the following characteristics are listed:

- Intermediate stops – The stations Bad Oeynhausen and Bünde are served alternating. Berlin Ostbahnhof is the last stop of the line in Germany. For later investigation, all stations in Berlin are summarised to one access and egress node. In this study, we calculate with 16 intermediate stops.
- Dwell times – The dwell time are around 2 min for intermediate stops except Hannover (“DB BAHN,” 2015).
- Frequency – The service is offered ones in two hours. In 2015, the there are six connections per day and direction.
- Capacity – The current train sets incorporate a bistro wagon, were food and drinks can be purchased. One train set offers approximately 550 seats. In contrast, the ICE offers 100 seats less.
- Turnaround time - The trip on the Dutch side until the border takes approximately two hours. The turnaround time at the border are comparable to the turnaround times in Amsterdam or Berlin (end stations). Although in Bad Bentheim (border station) the rolling stock is not cleaned, the turnaround time of 1.5 hours is necessary due to scheduling.
- Operational speed – In this study, the operational speed is described as the average speed between two stops, including dwell times at stations. A rough calculation shows for the IC Berlin that the operational speed is with around 100 km/h in the Netherlands lower. In Germany, the operational speed is 120 km/h. The operational speed is determine by the maximum speed allowed on a track, the maximum possible vehicle speed, the number of intermediate stops and the occupancy of the infrastructure by slower vehicles.
- Fare – For the international services, a revenue management is provided similar to the airline industry. This means that ticket prices increase, the closer the moment of departure. In order to understand the fare development, the prices are requested for three different moments in the future, namely booking ticket one (1), four (4) or eight (8) weeks in advance. The same is done for the car, bus and airplane, in order to understand, whether the train prices are high or low. The prices are retrieved from online ticket price calculators.

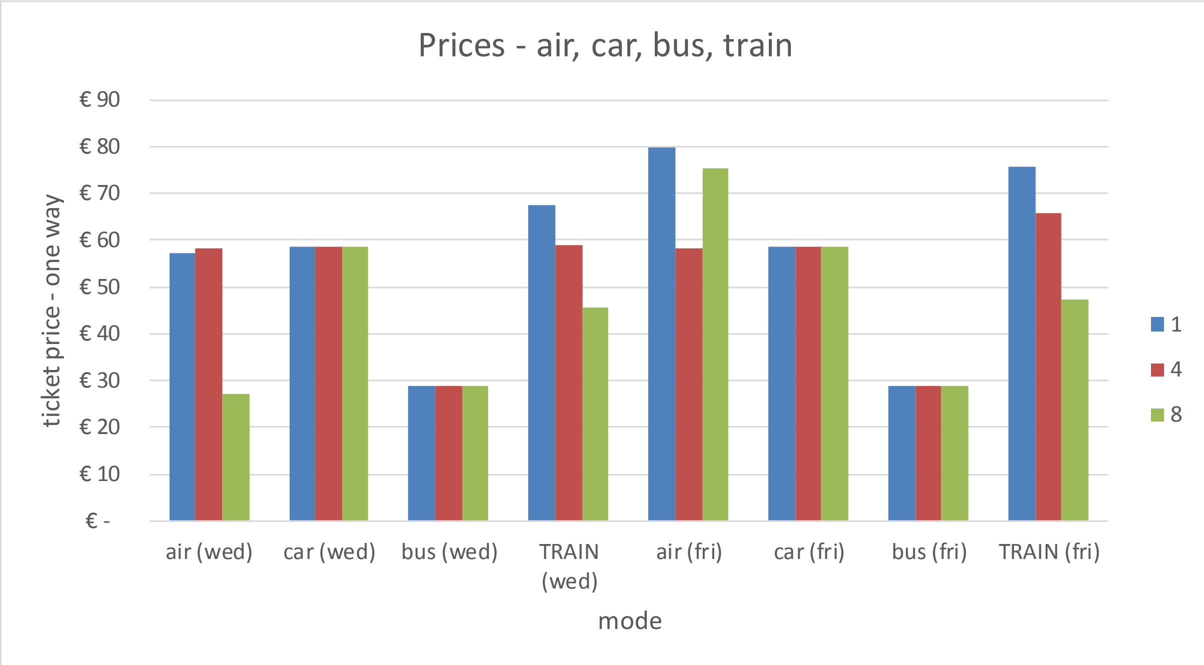


Figure 2-4: Price comparison among modes for the OD-pair Amsterdam-Berlin (online ticket purchase).

2.4 Stakeholder Analysis

The stakeholder mapping and analysis is an opportunity to picture various stakeholders, dependent on their level of interests (x-axis) and their level of power (y-axis). Changes of the existing international services affect various parties, who again affect the successful implementation of a changed service. In a first step, the different stakeholders are determined. In a second step, the relevant stakeholders are assigned to their interest and power level in the map. The location of all stakeholder is based on the knowledge collected within the Dutch operator. For the German side, similar stakeholders are assumed. The entire map is illustrated in Figure 2-4.

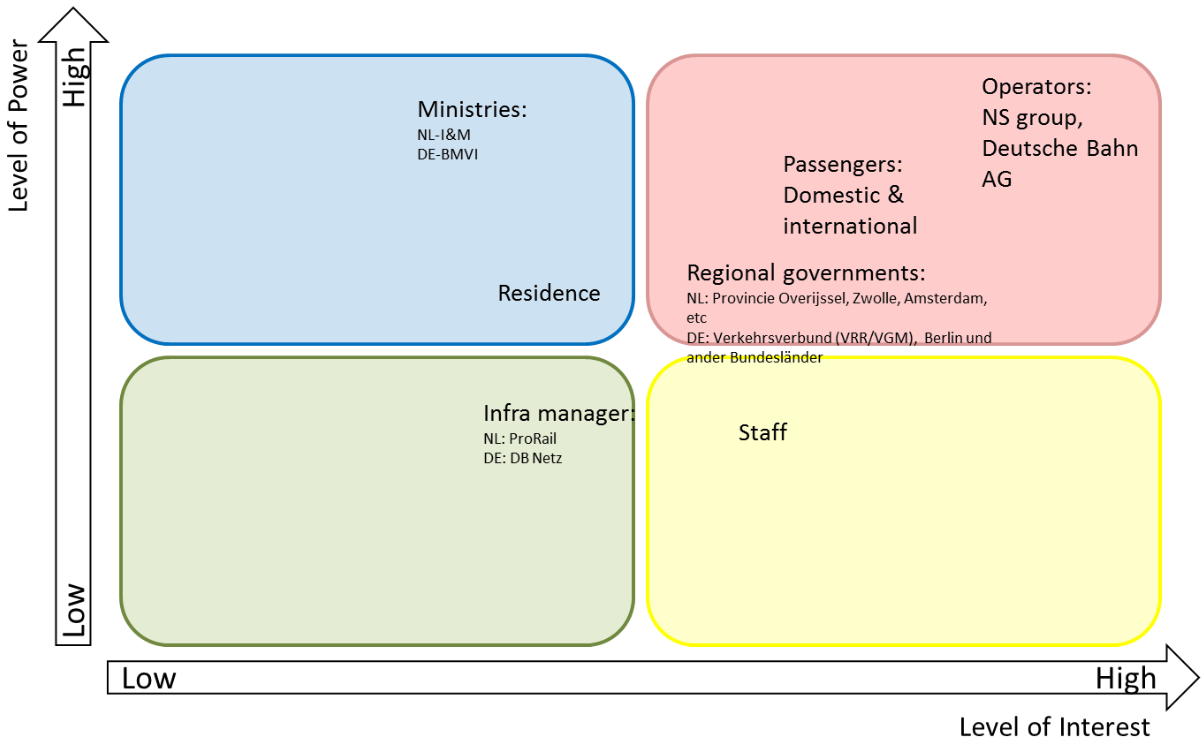


Figure 2-5: Stakeholder Analysis and mapping

The operators are displayed in the map as the parties with the highest level of interest and power. This is reasoned by the fact that they are initiators of the new service. Hence, they indicate a high interest and power to realize the eventual best solution.

Besides the operators of the rail service, also passengers are mentioned. If there is no demand of such a service, passengers do not buy tickets and hence directly influence the revenue of this project (power). However, the increasing demand of mobility is here related to a high interest of passengers on this line (Schafer & Victor, 2000). As third and last party, the regional governments are indicated. Assuming that the route of the future service between Amsterdam and Berlin changes, and different regions are served, reveals in tow aspects. First, the new regions will profit, due to the direct connection to Germany and an increasing frequency for national trips. Second, region that lose their direct connection to Germany will be worse off. The same hold for German regional authorities.

The group of parties with a high level of power but a rather low level of interests are indicated blue and are the ministries and residence. Certainly have the ministries a higher level of power than the regional authorities do. However, since the regional authorities are directly affected by a change of the current service, the national ministries are indicated with a lower level of interest compared to the regional authorities. The residence in contrast, have a lower level of impact, but can form strong resistance in case of new construction measures, higher noise pollution, etc. Examples are here the NIMBY[5] or BANANA[6] reactions.

In contrast to the blue group, the yellow group is indicated, with a high level of interest but a rather low level of power. Among others, personnel is listed here. Conversations with conductors and train drivers showed, that the overnight stays where a pleasant addition on their wage slip. The reduction of overnights in 2015, led hence to a dissatisfaction of employees. Furthermore, for the international connections, special train personnel is required, who speaks English and the two national languages. In this way, they are important for international services and listed in the yellow box.

In the fourth and last impact area, the infrastructure managers are listed. This group is very important for future services, as they provide the required infrastructure and support operators with the timetabling planning (ProRail). However, at this point of the study, it is unclear, whether new infrastructure is required. Furthermore, the choice of the final alternative will be based on a societal evaluation, which takes also the infrastructure manager interests into consideration. Thus, we assume that in case an alternative will be positive evaluated, ProRail as well as DB Netz will give their opinion on these alternatives, but not reject them. Their function is hence seen as a partnership, where both operator and manager rely on each other. It is hence placed in the middle.

2.5 Conclusions - Supply side

From the analysis of the Dutch-German network, the supply side of the study area is analysed. The insights help to answer the first sub research question:

(1) What defines international passenger train transport networks and what are the characteristics of the Dutch-German network?

In order to provide an answer to this question, the chapter examines four parts. First, literature is reviewed on the term international networks. Second, the network between Netherlands and Germany is closer examined. As a third, the relevant long-distance services are described, and finally some case specific aspects conclusions are given.

INTERNATIONAL NETWORKS

[5] NIMBY – Not In My Back Yard

[6] BANANA – Build Absolutely Noting Anywhere Near Anybody.

Due to the gap in literature on international transport, little references are found. However, the work of Nes, (2000), contributes to the general network classification and their hierarchies, where the international level is the highest. The author classifies public transport networks in different levels, which are related to the available spatial structure. Due to little literature over international transport, the study is considered as main definition for international networks. The highest level in the public transport network hierarchy "level A", provides two characteristics namely, travel distance and travel speed. These two attributes are used to *define* the international network:

- Travel distance – At least 300 km.
- Travel speed – From upon 160 km/h.

NETWORK NETHERLANDS-GERMANY

With the knowledge on network levels, the Dutch-German network shows two levels:

- Level B: Currently, there are five short-distance services on the interregional or regional level. They serve distances between 70 and 150 km. There is an increasing demand expected.
- Level A: The IC Berlin and ICE Frankfurt are located on this level due to their distances served (>300km). However, the operational speed is with 100 km/h below the classification of the international network. The maximum speed of 160 km/h is not achieved on the Dutch side. With the high amount of intermediate stops, the lines accomplish solely level B characteristics.

TECHNICAL ASPECTS

The comparison of technical aspects per network shows differences in overhead cable voltages, as well as for safety and signalling systems. Due to these differences, the simultaneous operation over both networks requires technical adjustments. For the IC Berlin, this reveals in additional operational time due to a locomotive change at the border. For the ICE, which provides multi current technique, higher investment costs are required. Besides the technical differences, shows the stakeholder analysis an increasing amount of stakeholders for international connections. Hence, for international connections we conclude the following aspects, which make the service *complex*:

- Technical differences complicate continuous transport. They can be solved with higher investment costs or additional travel time for travellers.
- Adjustments of international train networks affect a higher amount of stakeholders, than for national networks.

Finally, the following case specific supply characteristics are stated:

1. The Dutch-German train network does not provide operational speeds higher than 100 km/h.
2. Due to technical differences and old rolling stock, the IC Berlin requires additional time for a locomotive and crew change at the border (~10 minutes).
3. The train ticket prices are comparable to the costs for car and airplane (IC Berlin).

3 Train Passenger Transport Market

This chapter investigates the demand side of the research framework. In the first section, the transport demand between the Netherlands and Germany is presented. This section sketches the way from a line matrix and the national demand, over the combination of both matrices towards the demand forecast. Furthermore, the current mode shares and passenger characteristics are presented, derived from current NS customer surveys. The second section provides some general insights into train demand modelling, from which the elasticity model results. In order to determine the demand parameters, which are introduced as an additional step to the research framework, a twofold approach is chosen. The first part is provided in the third section and provides a literature study on demand elasticities. In order to specify these insights, expert interviews are conducted. They definition of international demand parameters as well as the reflection on the outcomes are reported in section four. The chapter ends with sub conclusions and the answer to the second sub research question.

3.1 Transport demand

In order to use the model explained in chapter 3, and hence test various alternatives for the intercity Berlin, the input side of the model needs to be provided. This implies a complete demand matrix, which can be later assigned to the network. The goal is to determine a multimodal OD matrix for the Dutch-German network for 2024. This is achieved by the following steps:

- Establishment of a base year matrix 2014 for national and international train demand.
- Extrapolation of the train demand using the growth factor method for 2024.
- Application of mode shares in order to estimate the complete demand over all modes.

The steps are described in more detail in the next subsections.

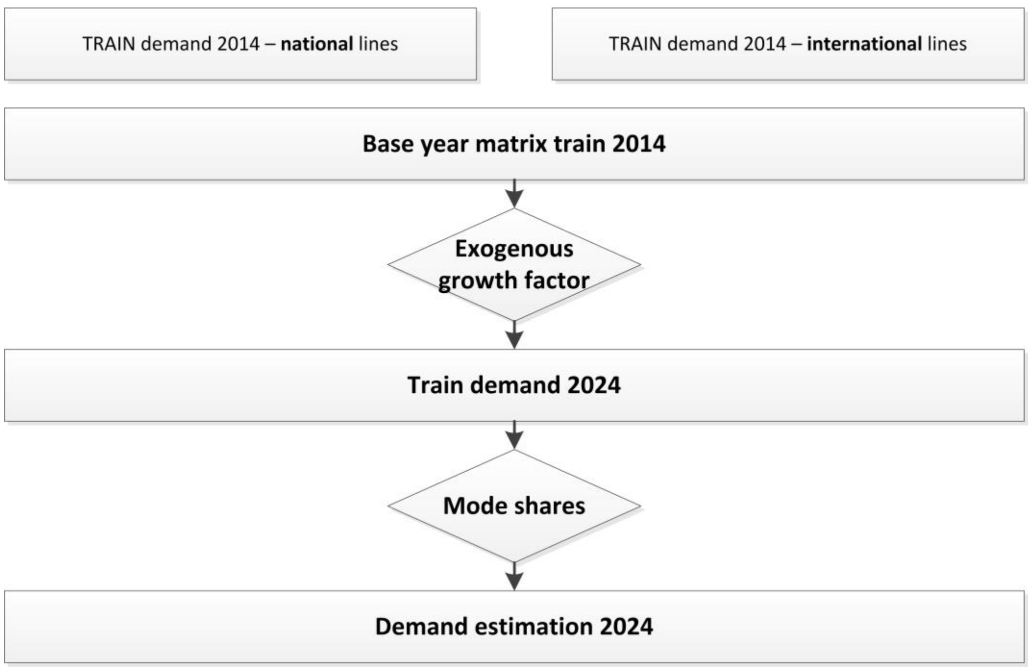


Figure 3-1: Framework transport demand 2024.

3.1.1 Establishment base year matrix 2014

For the establishment of a base year matrix, disaggregated or aggregate data sources are required. In any case, information about the production and attraction of a certain area is needed. For the market Netherlands-Germany, much aggregated data in form of ticket sale information is available, as cross-border service between both countries is provided for years. However, related to the fact that tickets for international trips can be bought in both countries over different distribution channels, and the fact that these are not directly related but each system collects their own data in different formats, the full overview is difficult to picture. From internal correspondence a rule of thumb is assumed with approximately one third of the international tickets are sold over the Dutch and two third over the German distribution channels. However, a standardization as for instance in the airline industry, where one main institution collects orders and distributes the total batch, misses in the rail industry. For financial and controlling purposes the different information sources need to be merged eventually. An important issue in this setting is transparency and data share among competitors. Although the NS and DB composed for the ICE to Frankfurt a joint venture, a certain wariness remains. The wariness even increases, if different to the joint venture agreement, services are divided in national parts, as it is given for the IC Berlin (see chapter 2). This hinders the complete overview.

To establish the base year matrix thus, various data sources are required. Especially for the German or foreign part, different sources are requested to grasp the full picture. The available data sources used for the base year matrix for the train demand 2014 are given in the following order:

(1) OD line matrix 2014 for
    a. IC Berlin
    b. ICE Amsterdam-Frankfurt
(2) Germany: Top-10 access/egress stations [%]
(3) Netherlands: National OD matrix 2014 [passengers/day]
(4) Ticket sale data for 2014 (NS).
    a. IC Berlin – with feeder traffic
    b. ICE Amsterdam-Frankfurt – without feeder traffic

With these four types of sources, the base year matrix will be established. One shall note the order of the sources. The line matrices (1) illustrate the classic OD matrix for the access and egress stations on the line. This source is commonly shared by the operators and gives an indication about passenger flows per day for all services provided that day. The intercity line towards Berlin is actually registered with number 77, the ICE towards Frankfurt is noted with 78 and the number 43. Nevertheless, for the sake of flow while reading, the lines are described with their German destination stations and train types, thus IC Berlin and ICE Frankfurt. These two connections are the only long-distance connections between both countries and form in that sense the total train demand in the current network. The main issue about the line matrix is that feeder traffic misses. The "real" origins and destinations are hence not visible. In case of an alternative service, demand might shift to other modes for instance and hence it changes per line.

Especially for the German or foreign part of the network, this information is crucial. Reliable ticket sale data would give more information about these OD relations, but due to different billing systems in both countries feeder traffic is rather difficult to readout for the German side. The DB however, provided an overview of the top-10 access and egress stations related to these two lines. The list of top-10 OD's represent around 80 percent of the entire demand. Furthermore, the OD pairs are at least one percent or higher of the total. Smaller percentages would lead to rather thin passenger flows with less than 5 passengers. For a model on an international scale, these thin flows are of little interest and hence excluded.

In the same way as the German top-10 OD's, the Dutch main stations (nodes) in the network are determined. This is achieved by using source (3), the national OD matrix. International traffic is there illustrated by flows towards a virtual border node. For the IC Berlin this node is placed between the German city Bad Bentheim, and the last city on the Dutch side Oldenzaal. In order to distinguish this node from the existing station, the node is called "Oldenzaal grens". For the ICE Frankfurt this node is set at "Zevenaar grens" respectively.

As a last source the ticket sale data available at NS was used. Due to inconsistency with the total in the line matrix, the previous mentioned sources (2) and (3) are essential. Nevertheless, these sale data indicates a global distribution of important Dutch and German stations over the cross-border destinations. In other words, this data source indicates the main distribution shares, even though the totals might be underestimated.

All four sources are based on annual data from 2014. This year-end closing is the most recent one. Furthermore, rather view big events influenced the demand in that year. In contrast, in 2013 the IC Berlin was limited offered for several months, as high water damaged the Elbe Bridge at Stendal. Thus, the demand in 2014 gives a robust indication of demand on a regular basis, which is extrapolated in the following step (exogenous growth factor application).

Given the available data, different steps are taken to establish the base year matrix 2014. In order to establish the base year matrix, four steps are conducted. They are presented in the following table. The left column illustrates each step; the right column shows explanations, assumptions or the approach used. All abbreviations are presented in Appendix N.

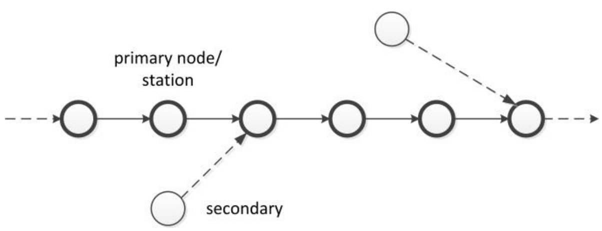
<table>
<tr><th>Step</th><th>Explanation</th></tr>
<tr><td>
1. Determination of the top-10 OD stations for the Dutch network.
<table>
<tr><th>ranking</th><th>Top-10 NL</th><th>Top-10 DE</th></tr>
<tr><td>1</td><td>Amsterdam</td><td>Berlin</td></tr>
<tr><td>2</td><td>Rotterdam</td><td>Hamburg</td></tr>
<tr><td>3</td><td>Utrecht</td><td>Hannover</td></tr>
<tr><td>4</td><td>Schiphol</td><td>Osnabrück</td></tr>
<tr><td>5</td><td>Den Haag</td><td>Bremen</td></tr>
<tr><td>6</td><td>Amersfoort</td><td>Bielefeld</td></tr>
<tr><td>7</td><td>Hengelo</td><td>Wolfsburg</td></tr>
<tr><td>8</td><td>Deventer</td><td>Kassel</td></tr>
<tr><td>9</td><td>Nijmegen</td><td>Leipzig</td></tr>
<tr><td>10</td><td>Leiden</td><td>München</td></tr>
</table>
Figure 3-2: Primary and secondary stations.


Figure 3-3: Top-10 OD's for NL and DE.
</td><td>

Only the international trips are considered towards, and from the border node by using the national OD matrix (source (2)). NL-border; border-NL
The top-10 stations compose between 70% and 80% of all demand, which is given in the line matrix.
Germany: The top-10 stations are extractions of the operator's demand model and provided by them. The percentages are aggregated to access and egress and thus assume to be symmetric (see Figure 3-2).
Netherlands: For the Dutch top-10 destinations more information is available. Hence a low asymmetry is found. The demand is by trend higher for the direction NL-DE than for the return connection (see total % Top-10 NL).
The stations along the line are indicated with capital letters in Figure 3-2 (e.g. ASD). As they are part of the line, they are considered as primary stations. Access/egress stations further away, which need transfers to enter the line, are called secondary stations (see Figure 3-3).

</td></tr>
<tr><td>2. Determination of the transfer stations (primary node) for each outer stations</td><td>

The transfer stations are derived from the

</td></tr>
</table>

(secondary node).

Table 3-1: Secondary stations assigned to primary stations.

IC Berlin

NL

primary secondary

AMF	Rdt	Ut	Gvc
HV	Shl		
DV	Nm		

companies' travel advisor (NS: ns international reisplanner; DB: Reiseauskunft - Fahrkarten)

- The resulting assignment of secondary stations towards primary stations is presented in Table 3-1. The return direction or the transfer stations for the ICE Frankfurt can be found in appendix … .
- For all secondary nodes the connections are tested for a Friday and in both directions.
- Some stations show alternating transfer stations depending on the departure or arrival period. In these cases the primary station is chosen, which appears the most. This mainly appears on the German side. One example is Karlsruhe, which uses mostly the transfer station Frankfurt Hbf but in the evening also an option is presented over Köln or Düsseldorf and another is even a direct connection ones per day (Line 43 to Basel).
- Cities with several stations as Berlin or Frankfurt are summarized to one station for reasons of simplicity, when assigning the secondary nodes to primary ones.

3. Extension of the given line matrix (1) by the additional secondary stations gathered from the list of top-10 OD's. Furthermore, the trip generation for secondary stations is applied using the percentages from source (2) and (3).

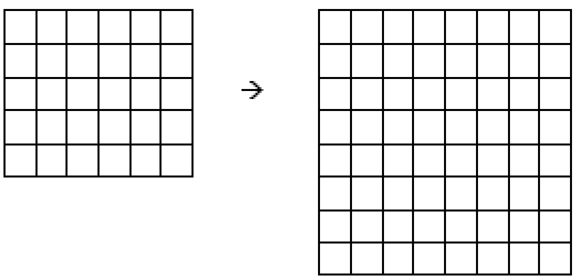


Figure 3-4: Matrix extension illustrated.

Together with Figure 3-3 and Table 3-1 the average

- The line matrices (1) determine the base demand between the Netherlands and Germany.
- The matrices are based on an average day in 2014. There is no differentiation between week- and weekend day or peak-moments. Also no distinction between 1st and 2nd class is made.
- The line matrices illustrated are slightly asymmetric. It shows more Dutch travel to Germany, than the other way around.
- For the ICE the top-10 OD's include the western and eastern areas of the Ruhrgebiet. However, analysing the connections to Amsterdam for the main cities located in both areas the transfer station appears to be for both areas

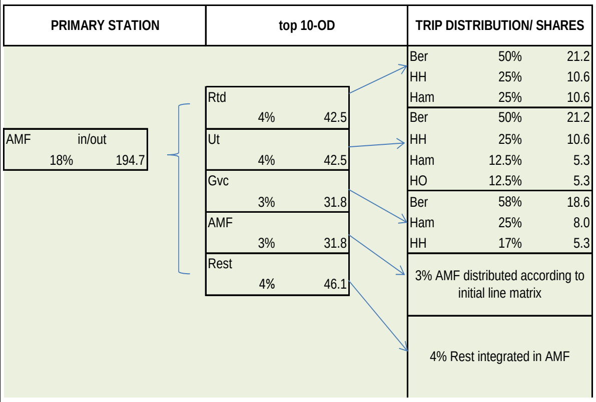
<table>
<tr>
<td>trips per day are generated for the secondary stations. Furthermore, the trips are subtracted from the primary stations, passengers transfer.</td>
<td>Duisburg.
• The resulting trip generation can be not provided due to confidentiality reasons.</td>
</tr>
<tr>
<td>4. Trip distribution over the main stations by using a “distribution tree”. (See Figure 3-5)


Figure 3-5: Trip distribution example with fictive numbers.</td>
<td>• For this purpose the shares are extracted from ticket sale data in 2014 (4).
• Secondary stations are assigned to the main destinations only. For instance for the ICE Rotterdam with a total share of 4% is distributed over the main stations Duisburg, Düsseldorf, Köln and Frankfurt according to the shares displayed in the ticket sale data.
• Berlin stations (Spandau, Hauptbahnhof, Ostbahnhof) are summarized to one station.</td>
</tr>
</table>

From the analysis of both services (ICE and ICB), the strongest OD-pairs result. Due to confidentiality the outcomes are provided only qualitatively:

DE-NL – Derived from the demand data, Amsterdam provides the highest attraction potential for international passengers. The most trips are booked to Amsterdam.

NL-DE – For German stations, such clear preference is not identified. The most passengers travel between Amsterdam and Köln, Dusseldorf, Berlin or Frankfurt.

3.1.2 Forecast 2024

In the previous section, the current demand is determined. In order to take a strategic decision for the time after 2024, the demand needs to be extrapolated. This will be done with a growth factor method, due to two reasons. First, the growth factor method is easy to apply. Second, the available data is limited. In general, the growth factor method uses a factor, to multiply the demand with. As there is no detailed information on specific OD-pairs, one factor is applied for the entire matrix.

Since the economic crisis in 2008 and the years after, the economy recovers. People are more willing to invest or travel for leisure trips. A similar line of reasoning uses NS to derive their national growth factor. In general, they take exogenous aspects as fuel prices, GDP, or population into account to determine the national growth factor. From these insights, they assume a national growth of two percent. However, this is mainly for short and daily trips. Additionally, a study for the international high-speed network is reviewed (Intraplan Consult GmbH & sma, 2011). The study accounts for the last economic crisis and predicts a growth for international transport by one percent. Moreover, European mobility surveys forecast an increase on long-distance trips (Violland, 2011). Thus, for the Dutch-German market a modest growth factor of one percent is assumed.

Thus, the base year matrix 2014 is multiplied with this growth factor to obtain the demand matrix for 2024.

- Base year x growth factor ^10 years = 10.46 % growth until 2024.

3.1.3 Mode Shares

In order to understand the market position of the train in comparison with the competing modes, NS conducts an annual customer survey. The insights are especially used for marketing strategies. This section summarises the main insights related to mode shares. For this comparison all available data is collected, which refers to the years 2011 until 2014.

The customer survey provides market shares for the strongest OD-pairs, among others for Amsterdam-Köln, Amsterdam-Frankfurt and Amsterdam-Berlin. Furthermore, these OD-pairs offer all four alternatives airplane, bus, car and train, which are compared during the study. In the following figure, the average shares between 2011 and 2014 are presented for each OD-pair.

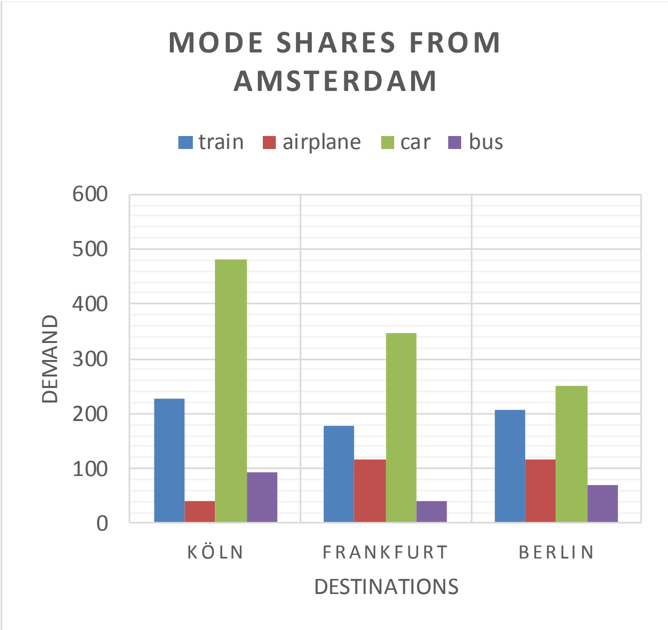


Figure 3-6: Mode shares between 2011 and 2014, from Amsterdam towards German destinations.

Figure 3-6 illustrates in the left, blue chart, the train demand. In relation to the total demand, the share of train trips is between 27 and 32 percent. In other words, the train share to the three presented destinations is around 30 percent. For the airplane, the lowest share is presented for the nearest destination Köln. For Frankfurt and Berlin the shares are comparable with almost 20 percent. Clearly the highest share has the car. However, Figure 3-6 illustrates that the car usage is the highest for the closest destination Köln (~250 km). The car share decreases for longer the distances (Frankfurt ~ 400 km) and is the smallest for Berlin (~ 650 km). Nevertheless, the car is clearly the dominant mode on the presented OD-pairs. The final mode for long-distance trips is the long-distance bus. Especially in Germany, different operators appeared since the liberalisation of the market in 2013. Since the bus offers the lowest prices compared with the other three modes (see section 2.3, Figure 2-4), the mode is considered as low budget mean of travel. As can be seen, the bus share does not increase or decrease with the distance, but is the lowest for Frankfurt (~5%) and approximately 10 percent to Berlin and Köln. This might be reasoned with the fact, that the low budget bus service is mainly attractive for passengers with little money and much travel time flexibility. Towards Frankfurt, more business trips are conducted, than to the remaining two cities.

3.1.4 Passenger characteristics – IC Berlin

From the customer survey, mentioned in the previous section, insights are gained considering the trip purposes. This section summarises the main insights regarding the passengers in the IC Berlin. Although only the last two years are available for this study, we assume that the passenger characteristics do not change tremendously over the years. In order to understand the share of national towards the international trips, realised data from the last 18 months are used. The insights are presented in Figure 3-7.

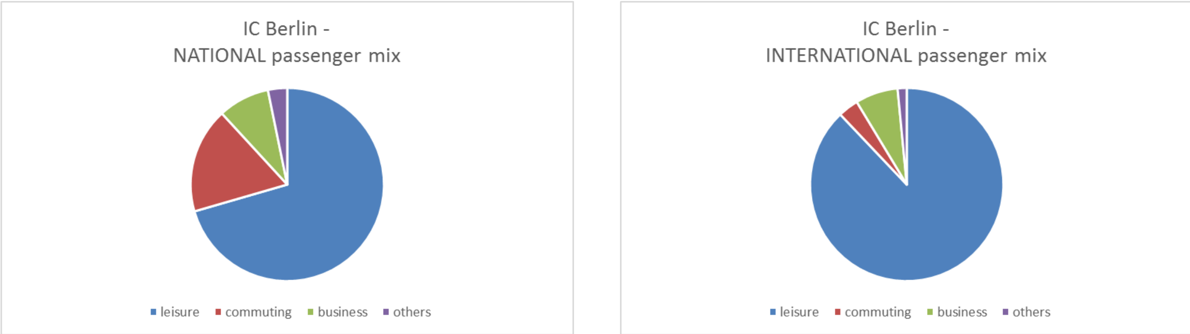


Figure 3-7: National and international passenger composition.

Figure 3-7 illustrates on the left side the national demand, split into the travel purposes leisure (~75%), commuting (~15%), business (~10%) and other purposes (<5%). As can be seen, national passengers use the IC Berlin mainly for leisure trips. For the international passengers, the share of leisure passengers is even higher. The share of commuters is constant, whereas the remaining two travel purposes decrease.

Furthermore, from the realised data it appears that almost 75% of the passengers in the IC Berlin are national passengers. Only 25% use the service to reach a destination behind the border. For the international passengers the customer survey reveals that in the years between 2011 and 2014, the average age of travellers increased from 39 to 46 years. The majority of the Dutch passengers is older than 50 years. Furthermore, this traveller group uses the service several times per year, which makes them an interesting target group. This passenger group is actively investigated in this study to provide more customised marketing strategies.

Finally, the customer survey documents that international passengers use the IC Berlin mostly on the Fridays and Sundays. The national passengers have their peak on the weekdays.

3.2 Literature review - Demand modelling rail

With the gathered OD data, the transport demand for 2024 for all modes is presented. However, this demand is based on the level of service or the transport supply given in 2014. For the NS as a commercial company, it is of high interest to be able to forecast demand changes. In research and praxis this is achieved by the use of models. Therefore, the following sub sections seek to provide an overview of common transport modelling framework.

3.2.1 Transport model overview

The classic transport model, also called the four- or five stage model uses zonal and infrastructure data to forecast transport demand. This literature study seeks to gain insight into the transport models and characteristics important for train trips. Thus, it is assumed that readers have a basic knowledge on the classic transport model. For readers interested in background information or further details are referred to (Ortúzar & Willumsen, 2011).

Literature found on train transport demand distinguishes between direct demand and multi-stage models. The main differences are the constraints necessary for the model. Whereas the multistage model uses the outcomes of the previous stage to determine the following sub model (stage), the direct demand model incorporates zonal and activity data in one function, and is thus not constraint to any previous choice. The direct demand model is hence mostly applied in inter-urban contexts or for models with large areas. Although the direct demand model is difficult to apply for areas with much information, it is not automatically worse off. In some cases, the model provides more robust outcomes (Ortúzar & Willumsen, 2011). This is in line with studies from the UK (PDFH B, 2009), which advice to use multi-stage models in cases where new infrastructure or transport means are introduced and demand cannot be deduced from the existing knowledge. However, if not all four stages are needed, as in cases where only the mode choice or trip frequency is required, a direct demand model is sufficient. In this context, the direct demand model is set equal to a single-stage model, where only one of the sub models is applied. In general, the advantages and disadvantages are summarized as follows:

Model	Pro	Con
Multi-stage	• Applicable for modelling new services, infrastructure, etc. • Due to many constraints calculations rather easy.	• Needs much input data. • Time intense.
Direct demand model	• Easy to apply for smaller changes in service. • Shows for inter-urban transport forecasts better results.	• Demand function is unconstraint and thus difficult to approximate.

When referring this knowledge to the Dutch-German market, it would be accurate to apply the multi-stage model. However, detailed information about traveller characteristics or zonal insights for an international context are not available (see also chapter 2). Therefore, the application of the 4-stage model is difficult. However, dependent on the available information, model stages might be left out. Additionally, not all stages are required. For example, an investigation on congestion requires only insight into the car usage. Thus, the mode choice step can be skipped.

In Figure 3-8 all stages (left) of the model are presented. On the right side, the sub models are shown. Afterwards, the stages are closer described.

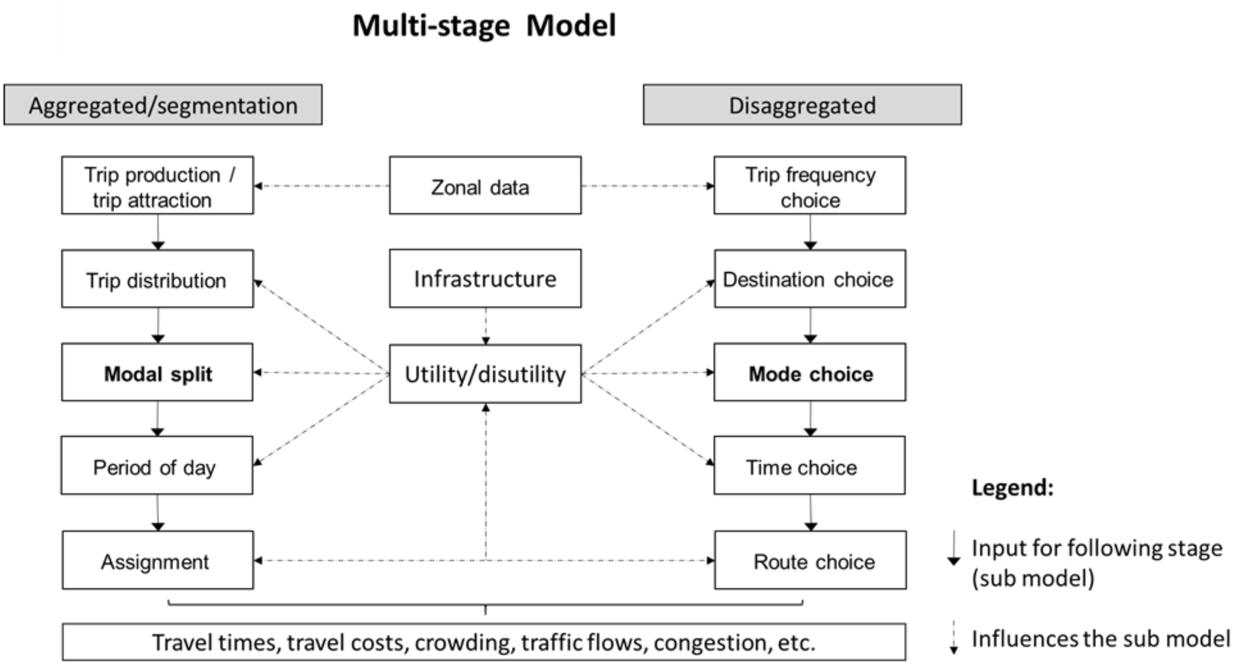


Figure 3-8: Multi-stage model (free after Erik de Romph, course CIE 4801, 2013)

Within the multi-stage framework the distinction needs to be made between aggregated models based on zonal data or disaggregated based on household or individual data. Depending on the available data, the model type aggregated (left column) or disaggregated (right column) is determined. Disaggregated models display the travel behaviour for each individual. In fact this has many advantages, as more precise information can be used. Typical information based on individuals are income, age, car ownership, access and egress time or precise location information about home, work, school, etc. However, the high level of detail also requires a lot of data, which is produced by conducting for instance a household survey, which are very costly in terms of money and time.

An aggregated source for train demand models are ticket sale data. Due to controlling and operation issues they are for most rail operators easy and thus relatively cheap to obtain. Only if the rail operators do not sell it via an own but partner site, the overview and correctness of all tickets sold, might be hindered (see previous section).

Furthermore, special tickets, as business or student cards limit the OD information on national scale. This holds mainly in countries as the UK, where a variety in Travelcards exists (Balcombe et al., 2004). For the Dutch-

German market this is only partly true. For cross-border connections it is required to purchase tickets. There is no international travelcard existing yet, which avoids the need of booking a ticket. Looking at the domestic trips Dutch public transport travellers are requested to check-in and check-out per trip, regardless, which discount ticket they own. For the German market exists, as far as known, only one travelcard type, the Bahn-Card 100, which does not request any ticket purchase upon front. However, latter is limited to the domestic traffic only.

The UK passenger demand forecasting council (2009) describes that the advantage of ticket sale data availability to such low price outweighs the disadvantages of less information about single travellers (age, gender, etc). Studies in the United Kingdom, mostly use aggregated data to estimate demand forecasts for rail.

Besides the advantages, two main pitfalls shall be highlighted. They consider the change of variables over time and their correlation. It is easy to understand, that for instance over the years the price might have increased as well as the number of passengers. Nevertheless, these variables can be correlated but do not have to be. Or in other words, the fare increase does not have to be caused by the increased number of passengers but for instance by inflation, energy prices, etc. And even if fare and number of passengers are correlated, they do not have to be causalities of each other. Thus, they might statistically appear together but do not be the reason.

In awareness of the pitfalls but with the high advantage of available data, the aggregated model is chosen for further investigations. All advantages and disadvantages are summarized in the following table.

Table 3-2: Aggregated vs. disaggregated model.

Model	Pro	Con
Aggregated model	• Easy to collect and thus cheap to obtain data. • For many train operators easy accessible (on a national scale).	• Not as accurate as disaggregated model. • Changes over year in demand might be correlated or not. The clear insight with aggregated data is missing.
Disaggregated model.	• More precise representation of actual travel behaviour per.	• Requires much data acquisition.

3.2.2 Transport model issues

After the choice for a certain type of transport demand model is made, the different issues relevant for train models are described. By choosing the aggregated multi-stage model one needs to understand how the available ticket sale data should be aggregated in order to group the data in homogenous groups. These groups represent input for the next subparts, as the mode choice model for instance. In order to understand choices, the factors influencing this choice need to be known. For the final forecast, the output of each model, not all stages within the model will be repeated, but the mode choice only. This saves computational effort and enables to model train demand directly. A common way to calculate this in train demand models is to apply elasticities. Therefore, this chapter incorporates the following points:

- Market segmentation
- Elasticities

Market segmentation

Even if aggregated data is used, different user groups appear, which again react differently on changes within the market. The segmentation is hence an important aspect when modelling. There are various ways to divide the market. The probably most common one is to split the users according to their trip purpose. These are business and leisure. Both can then be split up further for instance

- Business or commuting. Sometimes aggregated to business.
- Leisure (holiday, visiting friends and family, shopping, etc.).

Other segmentations can appear, when considering individual characteristics as gender, age, income class, car ownerships, etc. Or if looking at household data the household size, number of inhabitants within an age of 6-20 years (students), etc. However, due to the fact that ticket sale data is the most common and aggregated source used for rail demand forecasts, the first segmentation is chosen.

Elasticities

Elasticities are convenient to determine the impact of new measures or products on travel demand. They show the ratio of the percentage change in demand to the percentage change of a variable. For instance, if the fare elasticity is -0.5 the demand decrease by 0.5% if the fare increases by 1%. Changes in the service might influence travel time, the quality ("convenience" or reliability) or other variables, and thus change the number of trips made. Dependent on the degree of the impact and the alternatives a traveller has, the measure might lead to a behavioural change in the choice of trip frequency, destination, mode, time of day or route choice (Ortúzar & Willumsen, 2011). Nevertheless, in general elasticities summarize the impacts of changes in service together (Muconsult, 2015).

One should note, that elasticities are applicable solely for changes. The change in demand for new products, as for instance the introduction of a new transport mode cannot be determined by elasticities as they are a factorial change of existing (underlying) data. The demand for a new mode for instance was not determined afore and would hence be zero. Multiplying it with a factor would again lead to zero passengers, although this most likely would not be true. Another limitation of elasticities is the "size" of change. They reflect only small changes. For bigger changes, as for instance reducing the travel time by one half the same elasticity as used for small changes will not lead to the desired outcome (PDFH B, 2009). How to handle bigger changes will be further explained in the chapter "limitations" (will follow soon).

Elasticities can be composed using three ways. The first considers the collection of historical data. By inserting a demand time series on one hand and per series the related service supply, a so called back-casting method is applied to obtain elasticities. Another way to obtain elasticity factors is by gathering revealed or stated preferences. Both enable the analyst to gain an insight into the travellers' sensibilities when service changes. The third way, looks at the elasticities derived from model parameters, which can be extracted from discrete choice or linear models. Logit models for instance indicate characteristics of cross-elasticities (Muconsult, 2015).

When talking about elasticities two major distinctions need to be made, namely type of elasticity and the elasticity relation. In most literature there are two types of elasticities distinguished: direct and cross-elasticity. The elasticity relation, not derived from literature but especially created for this study, indicates which variable the elasticity refers to, for instance price elasticity. These two distinctions are important when reviewing literature. In addition to the relation (e.g. price), the demand unit needs to be clarified. Most of the studies refer to demand with number of trips made. However, there are exceptions where the demand is referred to passenger kilometres (PDFH A1, 2009). If nothing different specified, the here considered values refer to number of trips.

Another demand categorization found in literature is described with elastic or inelastic, depending on the absolute value. First is meant if the elasticity value lays above 1. Inelastic demand holds for all values between 0 and 1. Furthermore, the value can be either negative or positive, depending on the direction of change. For the example mentioned above, with a fare elasticity of -0.5, the value implies that by an increasing fare of 10 percent, the demand will decrease by 5 percent (change in contrary direction): -0.5 *10%. Would the elasticity be positive, would the demand increase with a raising fare (change in same direction).(Manheim, 1979)

Cross-elasticities describe the relation between two modalities, as for instance car and public transport or high-speed trains and planes. However, they strictly depend on current market shares of a certain mode composition and can hence not be easily used for other locations or future scenarios.

Limitations of elasticities

The limitations when using demand elasticities are summarised as follows:

- Ceteris paribus
    - This change holds under the condition that the rest remains unchanged or constant
    - "The Rest" are other alternatives, modes, routes, etc.
    - Changing more than one variable:
        - Usually form one model: thus simultaneous use passible

- However, if not from model (as here did with expert interview), an overestimation might occur. Reason: Increasing both, price and fare will be accounted two times. Solution: use of GJT= 0.6*0.3+0.9*0.5+0.2*0.2 ~GJT =0.7
- The same issue however, holds for GJT use elasticity → simultaneous adjustments will lead to higher generation/ reduction effects.

- Only for modest changes. (However, nowhere exactly defined what modest or small means.)
- Aggregated outcomes. (The demand changes are difficult to be assigned to a certain cause at a specific place (Wardman, 2014)).

3.3 Elasticity review and hypothesis

Using elasticities to illustrate the effect on demand when changing service attributes is limited (see chapter on limitations). Therefore, it is essential to analyse literature critically. Especially the choice of appropriate literature for a comparison, requires attention. "Comparing apples with oranges" might here result in misguiding outcomes. To avoid this, a practical framework is established. It serves as a review tool on one hand and as an assessment tool on the other hand. The framework is composed by five criteria, which are assumed to influence the values, given the limitations elasticities models have. These criteria are listed with distance, country, year, data and modes investigated and is presented in Figure 3-9. The found literature on elasticities for passenger train demand, is assessed according to these points. The framework helps to structure the literature review, by assessing each paper on exactly these and some additional aspects specific for each study. Using such approach ensures, each study is checked on the same criteria.

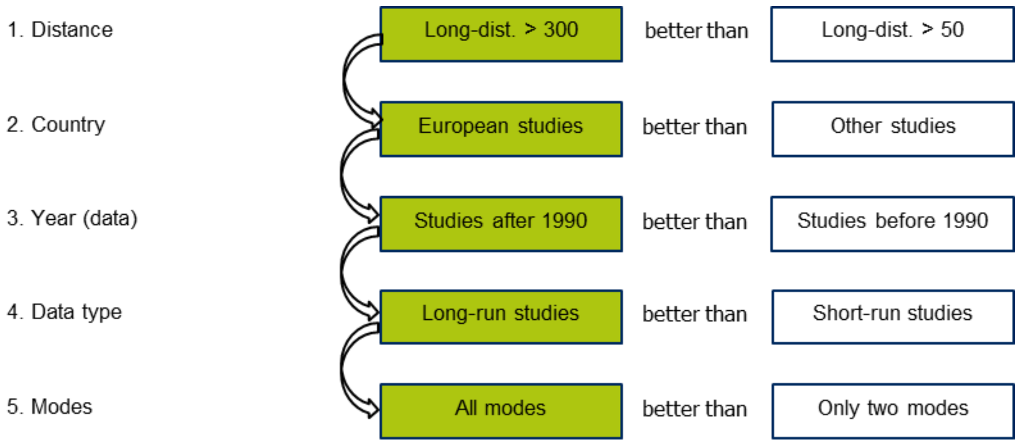


Figure 3-9: Assessment framework.

For the Netherlands, no article on long-distance transport demand was found. Almost all reviewed papers compare either mode choices, when introducing a new mode (e.g. HSR) or changing the service (faster, more frequent, etc.). Therefore, all papers refer to a mode choice model or direct demand model, which incorporates the mode choice level. Some articles present a variety of mode choice models, and aim to provide scientists with more advanced choice models as the base multinomial or binary logit. For comparison reasons thus, these papers indicate elasticities derived from base logit models and advanced ones . In order to make all different papers comparable, the elasticity values of the MNL models are drawn together and compared in first line.

As long-distance modes the coach, car, train and airplane are considered. However, in some studies samples for coaches were too small to be implemented in the mode choice analysis (Bhat, 1995) and needed to be hence excluded. In the German study from (Mandel, Gaudry, & Rothengatter, 1997) only the train modality is considered but then a comparison between high-speed and conventional train service is illustrated. In order to understand the demand change of one mode, if the service of a competing mode is changed, cross-elasticities are estimated. The long-distance bus service in Germany and Europe (e.g. MeinFernBus) shows an increasing demand (source..). However, this low budget alternative to travel is a rather new one. The literature reviewed, does not account for this trend as it was conducted for other markets where bus demand was insignificant. Overall, the modes rail, air and road are found, whereas latter includes private car only. The entire review according to the assessment framework is summarized in Appendix….

Two types of information can be distinguished when looking at the transport demand forecast. (Manheim, 1979) determines them as transport-system and activity-system related. More recent literature however, determines them as endogenous and exogenous factors. Endogenous factors refer to attributes per mode as for instance speeds, frequency, travel time but also comfort, punctuality, etc. The survey data together with socio-demographic data provides exogenous information as income, car ownership, population growth, economic growth, etc. (Cascetta & Coppola, 2014). With latter information type, direct demand elasticities can be determined. Applied are these direct demand elasticities to determine transport demand forecasts. Dependent on socio-economic (personal characteristics) and socio-demographic data (e.g. population growth, economic growth), demand curves are determined. When changing a certain service attribute elasticities describe the change in demand (see also chapter on elasticity description). The "exogenous demand elasticities" are not part of this literature review, as the forecasted demand in section 4.1. is established using the growth factor method. The difference between both methods however is minimal. The growth factor shows, equally to the elasticity of the demand, a per cent rise per later moment in time. For the elasticity, which is per definition an indication of demand change, when changing a dependent attribute by ten percent, leads to similar insights. Nevertheless, the direct elasticity describes the slope of the demand curve in one point (point elasticity), whereas the growth factor describes the slope of a linear trend among all demand points. In conclusion however, the growth factor incorporates the exogenous factors as GDP, car ownership, etc., with the determination of the slope of the trend line.

The literature review thus, draws together the found endogenous elasticity values. The findings are structured in four parts:

I. General findings

II. Specifications for the market NL-DE

III. Findings according to the market specifications

IV. Hypothesises and discussion

The first point summarizes insights which hold in general for the application of elasticities for train demand forecasts. In the second point the Dutch-German market is specified. These specifications are then used in point three. In a final hypothesis the values found in literature and filtered for the specific case are presented and discussed.

3.3.1 General findings

As the name indicates, the first point gives an overall insight. In later steps it is then zoomed into detail. For this section are more than ten studies reviewed. The selection of papers fallowed the review framework mentioned in 4.3. and described in appendix… :

a) Elasticity relations - (frequency, fares, travel times)

b) Trip purposes - (business, non-business, aggregated)

c) Regarded modes - (rail, air, road)

d) The models used - (MNL, BC, PL, others)

e) Assumptions made by the authors - (increasing service attributes, decreasing service attributes, improving service attributes – mixed)

f) Interrelation among trip purpose and elasticities

The illustration of the six points reports the interim findings of the literature study. In a later point these findings help to state elasticities for the regarded market between the Netherlands and Germany. All elasticity related papers are summarized in appendix.

a) Elasticity relations

When referring to endogenous elasticities, one speaks about the sensitivity of travellers towards changes in the service (of a certain mode). These so called service attributes describe the quality of the regarded transport service and might hence vary among the modes. For busses for instance Balcombe (2004) service attributes as the bus stop facility, seats, lighting, closed-circuit TV and bus service information are mentioned. For airplanes additional service attributes as on-board services or service integration with other modes are found (feeder traffic) (IATA, 2003). Besides the mode specific attributes, there are others, which hold for all modes.

Elasticities seeks to indicate the changes in demand when changing service attributes. For this reason, it is no surprise that nearly all studies reviewed, reflect on at least one of the following factors.

Table 3 2: Service attributes found in literature.

Frequency	Fares	Travel time

The travel time is a rather wide term. Dependent on the definition, the travel time might reflect on the time spent in vehicle, the time needed for access and egress the mode, or even the total door-to-door travel time. The latter incorporates not only in-vehicle time and access or egress time, but also waiting and transfer times. Wardman (2005) uses the term generalised journey times (GJT) as used in the Passenger Demand Forecasting Handbook (2009), which incorporates the station-to-station journey time, the service frequency and the interchange time, but leaves out the access/egress time. Pita (2005) mentions in their work the generalized costs (GC), which are similar to the aggregated perspective of the GJT, but translate the different attributes in a monetary unit instead of a time unit.

Due to the usage of a review framework, which concentrates on long-distance trips, it is stated that the three found service attributes are the most important for this type of trips. Other attributes as convenience or service reliability, are more evaluated in studies referring to public transport as in Muconsult (2015) or Wardman (2014).

b) Trip purpose

The segmentation of travel demand by trip purposes is one of the possibilities. Others are for instance the separation by ticket type (full-fare, season ticket, etc.) or by flow types. The latter for instance is used in the RIFF-Lite[7] model, applied in the UK. Nevertheless, the literature reviewed on elasticities does mainly reflect on two trip purposes:

Table 3 3: Trip purposes found in literature.

Business	Non-Business

Both purposes can be further split into sub purposes. Paulley (2004) for instance distinguish business trips between commuting trips and trips made for a business. The first indicates that people need to travel to get to their work or school. Their departure time is mostly fixed ("no other choice") and thus, they often travel during peak moments. Furthermore, business can be distinguished in paid business trips by an employer, or trips for business, the traveller needs to pay himself. Paid business trips are for instance used by Bhat (1995) or Koppelman (2000). Paulley (2004) explains that this group tends to be less sensitive to service attributes, as the ones who need to pay for their trips.

With non-business trips all other trips are summarized. Clark (2012) distinguishes for instance leisure day trips, visiting friends and relatives or holidays. Other authors add the purpose shopping. Over all non-business trips are characterized with a higher flexibility towards departure or arrival moments.

[7] Passenger demand forecasting model for train use (UK).

Gonzalez-Savignat (2004) state that these two purpose are important to distinguish, since they are different in type of journey and type of traveller.

However, in some of the reviewed studies, the distinction among different trip purposes is not given. In this case the elasticities are determined as aggregated values. The long-run study from Beherens (2011) for instance is based on a time series of 7 years. The goal there was to compare the average demand on HSR and air services between London and Paris. In this sense the authors simplified the outcomes by providing one aggregated value, although initially a distinction between purposes was undertaken. Park & Ha (2006) investigates the same modes for the corridor Seoul-Daegu in Korea. However, there is no clear indication, why the elasticity values are presented in an aggregated way, hence only presumptions can be made.

c) Modes

Cascetta & Coppola (2014) or Wardman & Et al (2005) determine the demand and the direct elasticities for the train only. The first mentioned study uses induced direct demand models to predict the demand for a future HSR service. Due to the fact, that this is a "mono-modal" model, the relation to other modes is out of the scope. The second study focusses, on a long-term research on the train demand in the UK.

The remaining studies aim to show the mode shift, when either introducing a new mode, or when changing certain service attributes. The following table indicates, which mode combinations are investigated.

Table 3 4: Mode combinations found in literature.

Rail (HSR), air	Rail, air, car	Rail, air, car, bus

Recently, much ex-post and ex-ante research is done on the introduction of a HSR service. Studies from Andrés López-Pita (2005), Behrens & Pels (2012a), Gonzalez-Savignat (2004), Park & Ha (2006) investigate this mode in comparison with the air services. However, one should note that the study from Gonzalez-Savignat (2004) and Andrés López-Pita (2005) in fact analyse the same case based on different attributes. Gonzalez-Savignat (2004) investigates endogenous factors, while Andrés López-Pita (2005) looks broader at exogenous effects.

The binary mode choice models, investigates the relation among two competing modes only. Other studies collect overall transport data for a certain corridor and thus include also travellers using car or bus. However, for the two Canadian studies, which are based on the same data set, the demand for bus services was too small and hence excluded from the research Bhat (1995) and Koppelman & Wen (2000). Similar holds for the Australian study from Hensher (1997) who investigates all modes, but finds two main relations, namely: The air-HSR market for business travellers and the car-HSR market for non-business travellers. The authors explain that people travelling by coach have mostly no other opportunity due to their socio-economic situation. For the further determination of elasticities the authors hence exclude the coach, as competing mode.

d) The models used

As mentioned earlier, Cascetta & Coppola (2014) uses an induced direct demand model and induced indirect demand model to forecast the demand for a future HSR service. Nevertheless, in general models can be classified in direct demand and multi-stage models (see also section 3.2.1). Within the second, the mode choice is one sub model (3rd stage). Nearly all empirical studies reviewed, refer to an econometric model, the well-known logit model. In addition the studies seek to demonstrate the advantages of using more complex models. (Bhat, 1995) for instance refers to the HEVL, while the same research setting is used by (Koppelman & Wen, 2000), to refer to the PCL. Thus, depending on the number of modes compared in the study, the authors refer to the binary or multinomial logit model on one hand, and some advanced models on the other hand. With advanced are also the nested logit models implied. The complete overview is presented in the following table.

Table 3 5: Models used in literature.

Base logit model	Advanced logit model
(linear, binary, multinomial logit)	(nested, heteroscedastic extreme value, paired combinatorial, box cox logit model)

The distinction between base and advanced logit model is important when reviewing and comparing elasticity values. Due to the IIA assumption, has the MNL the property to distribute the remaining mode shares equally on the alternatives. This is however mostly not the case in reality. Research hence seeks to find demand models, which distribute the demand in a more realistic way. (Bhat, 1995) and others explain that the base logit model overestimates the train demand. With the advanced choice models a better representation can be provided. When using the elasticity values from the MNL or BL one should thus, be aware of the overestimation of train passengers.

e) Assumptions made by the authors

Even if studies are investigating exactly the same data set with the same model, as for instance done by Bhat and Koppelman, the values are not exactly the same. This can be explained by the utility function and the used coefficients (or scaling parameter demand function). However, one should be alerted if signs of an elasticity value are different, although the same service attribute is referred to. One example is given in order to illustrate this situation:

Table 3 6: Cost elasticity for exactly the same corridor and trip business based on MNL.

	Train	
Rail service attributes	Business	
Cost elasticity	(Bhat, 1995) (Koppelman, 2000)	**- 1.951;** **+ 2.068**

This cost elasticities underlay different assumptions made by the authors, namely:

1. Increase vs. improve service attribute
2. Symmetric vs. asymmetric behaviour on service changes
3. Long-run vs. short-run studies

The first assumption relates to the direction in which the service attribute changes. When increasing the service, all regarded attributes change in the same direction (incline). This holds respectively, when services decrease (decline). However, if the authors refer to an improvement in service, the changes are in alternating directions. For the found service attributes implies an improvement an increase in frequency, and respectively a decrease in travel time and fares. Another example of this alternating assumption is the study by (Park, 2006). Instead of increasing the frequency, which is considered as positive effect on the demand, the authors increase the headway which has the contrary effect and hence decreases demand.

In order to make the found elasticity values comparable, one might hence decide to simply adjust the signs to the same direction. However, this influences the second assumption of symmetric and asymmetric demand behaviour. A symmetric demand behaviour implies that positive changes in the service attribute have the same impact on demand as negative changes. For example, the increase in fare would discourage as many passengers as the decrease in fare would attract. This assumptions seems to be less realistic than the asymmetric assumption. If the example of the Canadian studies really uses different coefficients in their utility functions (or scaling parameter) it cannot be derived from the papers (check this). Hence, the differences in relative values might be also explained by the asymmetry of the demand function. In the Canadian example this would mean that travellers are more sensitive to an increase in fare, as more people chose the train in absolute terms, and less sensitive to a decrease. However, (Paulley, 2006) and (Hensher and Block, 1979) determine the asymmetry the other way around. They state that more travellers react on a fare increase, than on a fare decrease in absolute terms. (Balcombe, 2004) argues that there is too little study undertaken on fare reduction and thus little evidence on asymmetric demand. One year later (Wardman, 2005) however investigates short-run and long-run effects and finds, that demand reacts on shocks in price and or delay asymmetric but on long-term overall symmetric. For this reason, we make the final assumption that demand behaves symmetric and hence, the signs of values can be changed.

The third and final assumption relates to the long-run and short-run studies. The first study from (Wardman & Et al, 2005) and the second from (Behrens & Pels, 2012b) indicate changes in demand over five and seven years respectively. One shall note, that changes in demand are not in general higher or lower for long-run studies.

However, studies related on a times series avoid the asymmetric shock reaction at the beginning, when service just changed. For symmetry reasons thus, long-run studies are preferred.

In conclusion, when comparing elasticities, one should be aware of the assumptions which underlay the stated values.

f) Interrelation among trip purpose and elasticities

Without selecting or summarizing the found elasticities, qualitative relations among trip purposes and elasticities are drawn. The following table illustrates them.

Table 3 7: Interrelation among trip purpose and elasticities found in literature.

	Trip purpose	
Elasticity relation	Business	Non-business
Frequency	More sensitive	Less sensitive
Cost	Less sensitive	More sensitive
Travel time	More sensitive	Less sensitive
Others	• Air biased • Alone	• Car biased • In accompany

Although the IATA survey does not directly present elasticity values, it provides some key findings for intercity markets (Iata, 2003). As presented, the study states that business travellers are more sensitive to frequency and travel time, than non-business traveller. The latter treads frequency and travel time in favour of costs. Or in other words, if the fare is low, passengers are willing to tolerate lower frequencies and longer travel times.

For the corridor Madrid-Barcelona, Spain, (Gonzalez-Savignat, 2004) the same relations apply. However, in their study they distinguish not only the two mentioned traveller groups but divide them further into sub samples as non-business passengers travelling in bigger groups or travelling more frequent. In these cases their sensitivity approaches the values of business travellers. Furthermore, they state that business travellers are most sensitive to changes in travel time. In contrast, leisure passengers find frequency the least important. The latter statement is equal to the German study (Mandel et al., 1997) and also (Goeverden, 2007) find this in his empirical work.

The long-run study on the HSR corridor Paris-London gives similar results for the interrelation between both traveller groups. Moreover, the authors explain relations between cross-elasticities for air and direct demand elasticities for rail. In general they state that cross-elasticities are smaller compared to direct elasticities in an absolute manner. Furthermore, they expect the relations between the two regarded trip purposes for cross-elasticities similar to the ones found for direct elasticities. However, this is only true for fares. Against their expectations, it appears that non-business travellers choosing the plane are more sensitive to travel times and frequency than business passengers.

Overall business travellers have another perception than non-business passenger. Therefore, when sorting the service attributes by priority, different authors ((Behrens & Pels, 2012a), (Gonzalez-Savignat, 2004), (Mandel et al., 1997) or (Goeverden, 2007)) state the following.

Table 3 8: Priority of service attributes by trip purpose.

Importance	High	Medium	Low
Business	Travel time	Frequency	Costs
Non-Business	Costs	Travel time	Frequency

A study on medium and long-distance trips by car and train in the Netherlands, concludes that the demand for train will increase for both traveller types in the future. This will be even encouraged if the travel time by car increases (Limtanakool, Dijst, & Schwanen, 2006).

3.3.2 Specifications for the market

The study conducted for the Dutch German train market by NS International in 2012, reveals a mix of different trip purposes per city travelled (see chapter 2). From the trips to Frankfurt around 40 percent account for business trips. The rest is summarized as leisure or non-business trips. However, looking at Berlin the share for business trips was with 13 percent registered much lower. As the general literature findings indicate, the perception of different service attributes for trains varies according to the trip purpose. This market segmentation is thus important. Furthermore, the considered market NL-DE offers different products, as the conventional IC Berlin or the ICE high-speed service. In order to investigate the entire market hence, different services need to be considered. Besides the market segmentation (trip purpose) and variation in services (train products), the market accounts for different modes. For a complete picture of the transport market, the total demand for all modes is required. Dependent on the study goal researches may choose to investigate one market only, for instance the train market. As this master thesis however, seeks to provide NS with a tool to investigate the Dutch-German and later maybe other international markets, it is desired to provide the complete transport demand.

As mentioned earlier, bus services are excluded from the review, due to little information on this specific mode choice. The Railteam data used to determine the mode shares, provides the so called "others" alternative. In order to stay as close to these modes shares as possible, this alternative remains unchanged. Since the mode is not clearly specified per OD, cross-elasticities cannot be applied. The fact however, that this mode accounts for rather low shares, justifies this neglect.

The two main train connections to Germany with around 400 km to Frankfurt and 600 km to Berlin are due to their long-distance interesting for air transport. The competing factor besides ticket price, is travel time. Accounting for the location of the airport, or the congestion at the airport Berlin, HSR and even conventional trains compete with the air transport. In order to consider this in the mode choice, the distinction between access/egress time and in-vehicle travel time needs to be made.

Thus, for the Dutch-German transport market, the following characteristics are stated:

- Distinction between both trip purposes, business and non-business.
- Direct demand elasticities for train.
- Cross-elasticities for airplane and car; bus needs to be excluded as no clear information about the amount of bus users within the mode share "others".
- Distinction between in-vehicle and out-vehicle travel time elasticity.

3.3.3 Findings according to the market specifications

In this part of the literature review on demand elasticities, different values are presented. The findings are sorted by the three service attributes found namely, travel time elasticity, fare or cost elasticity and frequency elasticity. The reviewed literature is briefly discussed following the assessment framework presented in section 3.3.

If the study fulfils a criteria mentioned in the framework, it is marked in Table 3-3 with green, otherwise is it left white. In this way one can easily note, which studies fulfil the most criteria and are thus considered of high relevance. As this approach helps to evaluate the different studies, it has similarities to a score card method. However, due to the fact that very different parts of the papers are regarded (content wise), and an insight in importance per criteria is missing, the score card tool is not appropriate. The relevance per study is indicated by the number of fulfilled criteria (see "score" in table). The entire list of literature reviewed is presented in the following table.

Table 3-3: Overview table with elasticity relevant literature.

	A	B	C	D	E	F	G	H	I	J	K	L
	year	author	distance [km]	country	data/year	data type	long/short-run	model(s)	elasticity relation	purposes	mode(s)	scores
1	1973	Kemp	short & long-dist	US, Europe	London, NYC <1970	time series; cross-sectional	long and short run	na	C, TT	b; n-b	C, transit	2
2	1995	Bhat	~600	Canada	VIA Rail/1989	RP	na	MNL, NL, HEVL	F, C, TT	b; n-b	R, A, C	3
3	1997	Mandel	> 50	Germany	KontiFern/ 1980	time series; or cross-sectional	short	LIN, BC	F, C, TT	a	R, A, C	2
4	1997	Hensher	>300	Australia	SP/1994	cross-sectional	short	HEVL, MNL	C	b; n-b	R, A, C, B	3
5	2000	Koppelman	~600	Canada	VIA Rail/1989	RP	na	PCL, MNL, NL	F, C, TT	b; n-b	R, A, C	3
6	2004	Gonzalez	~600	Spain	SP/2000	cross-sectional	short	MNL	F, C, TT	b; n-b	R, A	3
7	2005	Wardman	NLLD	UK	1995-2000	time series	long	meta; econometric	C, D, GJT, GDP	a	R	3
8	2006	Park	~300	Korea	self conducted survey	SP	short	BC	Acc, C, Hw	a	R, A	2
9	2009	(un-published)	>150	UK	smart card; counts; surveys	Mixed	short	na	F, C, GJT	b; n-b	R, A, C, B	3
10	2011	Behrens	~350	FR and GB	IPS/2003-2009	RP	long	MNL, mixed logit	F, C, TT	b; n-b	R, A	4

Legend

mode:	**R**	rail	**elasticity relation:**	**F**	frequency
	A	airplane	endogenous	**C**	costs/fares
	C	car		**TT**	travel time
	B	bus		**GC**	generalized costs
model:	**MNL**	Multinomial logit		**GJT**	generalized journey time
	HEVL	Heteroscedastic extreme value logit		**D**	delay
	PCL	Paired combinatorial logit		**Ac**	access
	NL	Nested logit		**Hw**	headway
	BC	Box-Cox logit	**elasticity relation:**	**Pop**	population
purpose:	**b**	buisness	exogenous	**Inc**	income
	n-b	non-business		**GDP**	gross domestic product
	a	aggregated			
data type:	**SP**	stated preference			
	RP	revealed preference			

Table 3-3 presents the 10 papers, which were reviewed on 12 points of content. Column C, D, E, G and K represent the criteria presented in the assessment framework. All studies are based on empirical research and include at least a basic mode choice model, as the binary logit. In the following, all elasticities found per service attribute are described according to the assessment framework. Based on this, a decision is made whether this study provides appropriate values for the Dutch-German market of not. We first start to discuss the travel time elasticity, afterwards the fare and finally the frequency elasticity. Studies which provide elasticities for each service attribute, will be assessed only ones. Hence, for every following service attribute, only the new studies will be mentioned and assessed. Each description concludes with a statement whether the presented study is appropriate for the DE-NL market or not.

According to the general findings, travel time is an important attribute for both traveller groups (business and non-business). For business passengers it is even the most important one. Furthermore, travel time is a broad term, which requires specification. Dependent on the study, it is defined as in-vehicle time or out-vehicle time, which are part of the total door-to-door travel time. In studies conducted for the UK, it is often referred to the generalised journey time (GJT), which includes station-to-station, headway and transfer times (Paulley et al., 2006). Due to these differences the found travel time elasticities need to be considered as different service attributes. The following table summarizes all values found.

Travel time elasticity

From MNL resulting elasticities when changing rail service attributes.

	Train			Air			Car		
Rail service attributes	B	N-B	A	B	N-B	A	B	N-B	A
Travel time (in veh.)	(2) -1.915; (5) -1.788; (6) -1.2; (11) -0.59/-1.1	(6) -1.0; (11) -0.24/-0.44		(2) +0.428; (5) +0.429; (11) 0.64/1.3	(11) +0.5/+1.57		(2) +0.428; (5) +0.429		
Travel time (out veh.)	(2) -2.501; (5) -2.927; (6) -0.23		(9) -0.4935	(2) +0.559; (5) +0.702		(9) +0.8641	(2) +0.559; (5) +0.702		
Travel time*	(1) -1.16	(1) +0.18	(1) -1.29; (3) -0.63;						
GJT			(7) -0.7/-0.85; (10) -0.7/-1.1;						

Travel time* is not clearly specified in the reviewed papers.

Legend

(1), (2), ... Number indicates which study is used listed in overview table.

[black] These found values will be used for later investigations.

The first study from (Kemp, 1973), investigates travel time elasticities based on demonstration projects and cross-sectional models. For this reason he does not limit his study to one area, but investigates projects in Europe as well as in the US. These different projects are based on different data sets, which reveals in short-run studies as well as long-run studies. However, the data sets are from 1970 and older. It is most likely that the exogenous, as well as endogenous information changes that much, that the study is not useful for the market NL-DE. Furthermore, the authors do not specify unambiguous the term travel time. From the context however, we presume that they refer to door-to-door travel time. From the study different travel time elasticities follow for different trip purposes. As non-business trips the authors present either visits or shopping trips. As we are interested on long-distance attributes for the NL-DE market, visits seem to be the most comparable trip purpose. Remarkable is the positive sign presented. With an increase in travel time, more visits are made by train, but less business trips (negative sign). The exact explanation is missing. According to the assessment framework the study fits positively to only two criteria. Overall, we find this study thus not applicable for the NL-DE market and excluded it from further considerations.

(Bhat, 1995) investigates the case Toronto-Montreal, which is approximately 600 km long and hence fulfils the first criteria. The data set is collected in 1989. Very positive about the study is the fact, that revealed preference experiments are conducted. As they indicate actual travel behaviour they promise to show the best accuracy (Román, Espino, & Martín, 2007). The study present direct demand elasticities for train, and cross-elasticities for airplane and car, which makes the study interesting. Although, the corridor is not within the EU, we might derive from the recent GDP per capita in this country, that their standards are comparable with the ones in the Netherlands or Germany. The disadvantage of this study is the fact, that only paid business travellers are examined. As the study is conducted to show impacts of new transport policies, it is assumed that paid business passengers are the most significant traveller group on this corridor, which is not in line with the Dutch-German market. Nevertheless, due to provision of direct and cross-elasticities and the clear specification of at least one, of the two desired trip purposes, we consider the study as a reference case. Furthermore, the study fulfils three out of five assessment criteria.

The only German study (Mandel et al., 1997) is based on the KontiFern survey from 1980. The study considers the three modes of interest. The main goal of this study is to investigate the advantages of using a non-linear Box Cox model. Positive characteristics of this model are the non-linearity, which can handle even significant changes in service (e.g. decreasing the travel time by one half). However, an indication about cross-elasticities is missing. The three elasticities travel time, fare and frequency are presented as direct elasticities per mode. Although the survey contained information about trip purposes, the elasticities are given as aggregated values. Furthermore, the travel time is not closer defined in the study. In conclusion the study provides interesting aspects, as it is for the German long-distance market and considers both, conventional and high-speed trains. Nevertheless, the used data is rather old. In total the study fulfils only two assessment criteria. Furthermore, no cross-elasticities are provided, which makes it difficult to use this study as a comparison. We therefore choose, to not use it for the elasticity hypothesis.

As the fourth study includes no travel time elasticity it will be explained later.

The fifth study by (Koppelman & Wen, 2000) is subject to the same corridor as the study conducted by (Bhat, 1995). Respectively, the same advantages and disadvantages hold for this study. The major difference are the choice models they use. Whereas Bhat investigates, among others, the HEVL, makes Koppelman use of the PCL. However, both studies provide elasticity values for the MNL too. Although the studies investigate the same corridor based on the same data set, the absolute values differ. This is related to the different assumptions they made on one hand (increasing attributes vs. improving attributes), and the differences in utility functions on the other hand. One might note that Koppelman's demand function gives in-vehicle travel time a higher elasticity and out-vehicle travel time a lower one, compared to (Bhat, 1995). However, the differences are rather small.

(Gonzalez-Savignat, 2004) investigates the impact of a new high-speed line between Madrid and Barcelona, on the available air transport market. This corridor is about 300 km long. As the study investigates the demand for a new transport service, elasticities are derived from another existing case in Spain, the Madrid-Seville corridor. The authors talk about a MNL but with two modes, they actually refer to a BL. Due to the linearity limitation of the classical model, the heterogenic travellers are split into various sub samples. Hence, there is not only a distinction between business and non-business but also between leisure passengers travelling frequently, in groups, alone, etc. In order to combine the disaggregated individual elasticities to aggregated ones (e.g. business and non-business travellers), they use weighted averages (Dunne, 1984). When comparing these obtained absolute values with the others available, the big differences become clear. This might be reasoned with the averages the authors use, which over- or underestimate certain values. Comparing these values with the Canadian studies, we note big differences among the absolute values. This might be related to the differences in market, or differences in assumptions. However, due to missing evidence, we can give no confident explanation for these differences.

The UK long-run study from (Wardman & Et al, 2005) is based on a data series from 1995 until 2000. Their market segmentation is based on flow types, and hence trip purposes are not distinguished. The flow types however are different for the entire country. The most applicable when referring to the Dutch-German market are the non-London long-distance trips (NLLD). However, as the NLLD trips are not closer defined, it is most likely that these flows incorporate both, trips above and below the 300 km margin. Furthermore, the authors provide not travel time and frequency elasticity separate but incorporate them to one GJT elasticity. As the study seeks to investigate asymmetric demand when increasing or decreasing service attributes, an aggregated elasticity is sufficient. For the Dutch-German market, where service attributes shall be changed separately, a use of the GJT seems a strong simplification.

(Park & Ha, 2006) investigate a 300 km long corridor in Korea. Similar to the study from (Gonzalez-Savignat, 2004), the goal of the study is to investigate the impacts on the air transport with the introduction of a new high-speed line. The SP experiment among air travellers was conducted recently by the authors. A distinction between trip purposes is missing. The reason for this is not specified by the authors. Hence, the value can be found in the column for aggregated elasticities. The authors decided to investigate the out-vehicle travel time only. As this study is the only one indicating this value for aggregated purposes, it can be not compared with other study outcomes. Due to the fact that this research scores only with two on the assessment framework, we exclude it from the further hypothesis.

Last but not least, the study from (Behrens & Pels, 2012b) is discussed. The study focusses again on the competition among HSR and air services on the corridor London-Paris and is thus above the 300 km. Among all reviewed studies it is the most recent one and based on long-run data. The study clearly distinguishes among both purposes. Comparing the absolute values with the other studies, one observes two things. First, the values are rather low within the same attributes and trip purpose. Second, the direct elasticities for train and cross-elasticities for air have comparable absolute values. This is mainly explained by the fact, that the HSR (Eurostar) has a very high market share, due to the unattractive access time towards the airports. In total the study fulfils four out of five assessment criteria with green. Therefore, it is desired to serve as a reference.

Nevertheless, one should bear in mind, that this binary choice model investigates very similar alternatives and gives hence, rather low elasticities (underestimation).

Fare elasticity

Table 3-4: Fare elasticities – literature.

From MNL resulting elasticities when changing rail service attributes.

	Train			Air			Car		
Rail service attributes	B	N-B	A	B	N-B	A	B	N-B	A
Cost	(1) -0.87; (2) -1.951; (4) -1.026; (5) -2.068; (6) -0.57; (10) -0.6; (11) -0.09/-0.12;	(1) -0.77; (4) -1.367; (6) -1.34; (10) -0.9/-1.1; (11) -0.58/-0.95	(1) -0.19; (3) -0.13; (9) -1.0312	(2) +0.436; (4) +0.202/0.302**; (5) +0.496; (10) +0.25;	(10) +0.05	(9) +1.8060	(2) +0.436; (5) +0.496; (10) +0.1	(4) +0.008; (10) +0.3;	

In general, the most literature found on demand elasticities refer to the fare elasticity. However, in some studies it is called price or cost elasticity. The sensitivity of demand, when changing fares is often discussed for public transport and thus, short-distance travel. Examples are for instance (Paulley et al., 2006) or (Balcombe et al., 2004).

All found fare elasticities are listed in Table 3-4. Due to the fact, that some values belong to the studies, excluded from further consideration (grey values), only few values remain relevant (black).

Study four by (Hensher, 1997) only investigates fare elasticities. For the 300 km long corridor between Sydney and Canberra, Australia, a stated preference experiment was conducted in the nineties. All three modes were investigated for both, business and non-business passengers. However, the authors derived from this survey that business passengers make the most use of HSR and an airplane, whereas non-business passengers choose between HSR and car. Elasticities are thus only provided for this binary choice model. Similar to (Bhat, 1995), (Hensher, 1997) uses the HEVL and gives the MNL values only for direct demand elasticities. All cross-elasticities are derived from the HEVL. This explains the rather low cross-values for car. Note, they are not comparable with obtained values from (Wardman & Et al, 2005). The authors further distinguish between different ticket types, as first, economy or business class. This was not done in other studies. We chose HSR economy class for direct demand to make the values the most comparable to the remaining studies. In total, the study fulfil three out of five assessment criteria. We therefore decide to use the direct but not the cross-elasticities as they are simply not comparable.

Frequency elasticity

Table 3-5: Frequency elasticity.

From MNL resulting elasticities when changing rail service attributes.

	Train			Air			Car		
Rail service attributes	B	N-B	A	B	N-B	A	B	N-B	A
Frequency	(2) +0.303; (5) +0.333; (6) +0.18; (11) +0.3/0.56;	(6) +0.10; (11) +0.12 / 0.23	(3) +0.19; (9) +0.0973;	(2) - 0.068; (5) -0.080; (10) -0.25; (11) -0.3/-0.65	(10) -0.05; (11) -0.26/-0.58;	(9) -0.1703	(2) - 0.068; (5) -0.080		

Legend

(1), (2), … Number indicates which study is used listed in overview table.

[black] These found values will be used for later investigations.

[grey] The grey values will not be used further.

For the last service attribute, frequency, (Bhat, 1995), (Koppelman & Wen, 2000), (PDFH B, 2009) and (Behrens & Pels, 2012b) will not be discussed again. Nevertheless, we emphasise that the outcomes are in line with the general ones. So from all three reviewed service attributes, shows frequency the lowest values. Furthermore, business passengers are more sensitive to frequency than non-business passengers. The Canadian studies even imply a very small effect on competing modes, when changing this attribute.

The (PDFH B, 2009) study provides only cross-elasticities for frequency changes. However, as it is used for the other service attributes as reference, it cannot be excluded for this comparison.

3.3.4 Hypothesis and discussion

Together with the assessment framework literature was reviewed and assessed by criteria, which are in line with the Dutch-German market. As a following step the different findings will be drawn together. First general remarks are given, afterwards the final values for the service attributes travel time, fares and frequency are presented.

From the in total eleven studies reviewed, six studies needed to be excluded from further considerations. Looking at the remaining values, one might argue that the most reliable findings are the one obtained by study (2) and (5) as these two are very close. However, one should bear in mind that (Bhat, 1995) and (Koppelman & Wen, 2000) investigate the same corridor based on the same data set. In order to avoid a biased towards these two studies, the earlier study will be erased from the findings. We assume that the later study incorporated newer insights and thus the values are more reliable.

Although initially the most literature was found on fare elasticities the picture is now rather balanced. The less comparable studies are found on cross-elasticities among conventional trains or HSR in comparison with cars. Due to the transport development in the last decades it seems to that the most interest in research is placed on new developments as the HSR introduction. Classical transport means are less investigated in this context nowadays.

Looking at elasticities derived from studies with subject to HSR and air competition, one might observe that absolute values are rather comparable. For instance study (11) by (Behrens & Pels, 2012a), refers to the HSR and air traffic between London and Paris. The authors explain that the HSR has nearly 50 percent of the share and is comparable with offered air services in time and price. In conclusion there is no surprise that the direct demand and cross-elasticity values are rather close.

In contrast, the values of the Canadian study (5) (Bhat, 1995) are presented. These are rather high for train and considerably lower for air and car. For now we did not investigate whether the service are similar in fare and time or not, but the absolute values imply, that using them will have a bigger impact on the train demand, when using the values presented from the HSR and air binary logit models. Thus, using these values is considered to have an optimistic effect on travel demand. Using the elasticity values obtained from the HSR binary logit studies, are considered as pessimistic respectively. Supported is this statement by the authors from the Canadian study, who explain in their conclusion the effects when using a MNL. They explicitly refer to the overestimation of train usage resulting from the application of MNL models. Furthermore, they stress the fact that a MNL is due to its properties limited when applying cross-elasticities. One might argue, that therefore the advanced logit shall be used or in case of the study from (Koppelman & Wen, 2000), the PCL model. However, as the HSR study does not investigate the PCL model too, the presented elasticity values would be not consistent anymore. For this reason we decide to stay with the MNL model although, the MNL is very limited when referring to different alternatives.

In the following table the elasticities are presented resulting from the literatures review. The results are presented by the trip purposes business and non-business and the three main service attributes found in literature, namely travel time, fares and frequency. Since the literature indicating elasticities for aggregated trip felt out in the previous step, these elasticities not listed anymore and the trip purposes is erased. The resulting values are summarized in a range. For example for we found the direct demand elasticity for train use within a range of -0.6 to -1.8 when increasing the in-vehicle travel time by 10 percent. A single value indicates that only one study provides this type of elasticity. The values are rounded to one decimal place.

Table 3-6: Resulting elasticities from literature review.

From MNL resulting elasticities when changing rail service attributes.						
Rail service attributes	Train		Air (cross-elasticity)		Car (cross-elasticity)	
	Business	Non-Business	Business	Non-Business	Business	Non-Business
Travel Time						
in vehicle	-0.6 to -1.8	-0.2 to -0.4	+0.4 to +1.3	+0.5 to +1.6	+0.4*	**
Fares	-0.6 to -2.0	-0.6 to -1.1	+0.3 to +0.5	+0.1*	+0.1 to +0.5	+0.3*
Frequency	+0.3 to +0.6	+0.1 to +0.2	-0.1 to -0.7	-0.1 to -0.6	-0.1*	**
*	For this elasticity only one reference value is found.					
**	For this elasticity no reference value is found.					

Overall, the presented elasticities show two issues:

1. Wide range of values.
2. Some values are missing.

The wide range can be solved by either an introduction of optimistic and pessimistic scenarios, or the obtained values are evaluated by experts working in the field of train transport demand modelling. The second issue refers to the gabs, which could not be closed by literature, as for instance the out-vehicle travel time elasticity for non-business passengers. Again there are two options to handle this issue. Firstly, the service attribute out-vehicle travel time will be eliminated. As the OD demand is determined by ticket sales per OD pair, on not by using survey data, the catchment areas are not specified. Hence an average determination of the access and egress time is considered to be rather difficult. However, this is required if out-vehicle travel time elasticities shall be applied. The second option to fill the gaps, also for instance for the GJT cross-elasticity for the competing modes, is again the consolidation of experts.

3.4 Expert interview

Due to the wide range of elasticities found in literature on one hand and the little reference values on the other hand, uncertainties in the values are undeniable. The uncertainty mostly appears due to differences in models and data used. For some studies the context is close to the Dutch-German situation for others less. In an optimal research situation with unlimited resources as time and money, the elasticity values are gained by detailed surveys. However, due to the available means the elasticities are obtained by first, reviewing available literature and second, interviewing experts. The latter will be conducted using a semi-structured interview approach.

In this section first the approach will be described and a brief overview of the strong and weak characteristics of this approach will be provided. Afterwards each step described in the approach will be conducted. The section ends with the analysis of the expert interviews. All interviews are anonym and can be found in Appendix B.

3.4.1 Semi-structured approach

In order to evaluate the found values and achieve a higher certainty in correctness, different experts from the railway sector are asked on their opinion. For this reason a semi-structured interview method is chosen, using the following steps:

1. Selection of the participants
2. Contacting the participants

3. The interview project plan
4. The interview means
5. Approval by the experts

The semi-structured interview is situated between the structured and unstructured interview type. It provides interviewees with open-ended questions and close-ended questions. In general, this type of interview provides the research to gain specific information on one issue, while also allowing for further explanation when new point emerge. These type of interview is especially useful, where the researcher has only one chance to interview a person. The interview method gives the opportunity to gain insight into qualitative and quantitative relations. In the following, advantages and disadvantages are be briefly mentioned. The main sources used are (Diagnosis, Kit, & Local, 2009; Wilson, 2014).

Advantages

- Structured questions upon front lead to a professional character. However, with the opportunity for participants to elaborate on their opinions, the interview gains on additional information
- Freedom for participants to express their views in own terms
- *CAN* provide reliable, comparable and qualitative data. However, this depends on the number of participants and the outcomes.
- Provides not only answers but also reasons for the answers.
- During face-to-face interview interviewee may discuss more sensitive issues than doing it by hand/ on paper only.
- Useful when studying a specific situation.
- Useful when supplement or validation for earlier derived outcomes is desired.
- Helps to get insight into problems which are not immediately recognizable but important in this field.

Disadvantages

- Among the additional information might be also useless information given by participants.
- The questions need to be unambiguous for the interviewee. Furthermore they should not be vague or insensitive.
- Test trails are necessary, which need extra time and preparation.
- Although the questions shall be open-ended as well as close-ended, the interviewer is supposed to lead the questions, which might be difficult for some people.
- Questions might be wrongly judged by the interviewer.

In conclusion, the semi-structured interview approach combines both worlds of structured and unstructured approaches and thus incorporates the advantages mentioned above. However, the interview need good preparation and post-processing to highlight the main disadvantages. Nevertheless, caused by the little insight into the Dutch-German market on elasticity factors and influencing service attributes, the opinion of experts on this topic reveals in additional insights, which are desired.

3.4.2 Expert group

GROUP COMPOSITION

(Diagnosis et al., 2009) recommend to use the stakeholder analysis when choosing participants for the interview. In this way the most different but related parties can be approached. In general, an adequate participant is someone, who understands the topic because of his or her position, activities or responsibilities, a so called "witness of the problem situation".

The exact number of participants is not clearly defined and varies per study purpose and goal. However, there are several issues pointed out:

1. The number of participants needs to be higher, if the interview is the only source and lower, if the interview serves as a supplement of data collected by other sources.
2. The number of conducted interviews is sufficient, if the answers provide repetitive information.

Due to the specific topic, the elasticities for the Dutch-German train market, the number of participants is limited. Other stakeholders, as for instances members of the Dutch Ministry of Infrastructure and the Environment were consulted. However, they rejected the participation, as they felt not expert enough to give their opinion on this specific topic. Similar to others, they referred to colleagues from the railway industry. Due to confidentiality reasons, names of companies as well as respondents are excluded from this report.

CONTACT PARTICIPANTS

The experts participation is asked upon front. From the five asked, four agreed on an anonym participation. One refused the participation due to consciousness in this field of expertise. The remaining candidates are experts on demand modelling for train passenger transport. The first contact was indirectly over colleagues related to the case study Amsterdam-Berlin in a wider sense. After they received a positive answer, the participants received a first information email about the study and gaol of this interview. In a second email the participants were asked for a precise telephone or face-to-face appointment. Finally the experts received a last email with the request to check, whether answers and comments are summarized properly.

3.4.3 The interview project plan

The interview project plan consists of seven questions, and several sub questions. The entire plan is listed in Appendix B. The questions distinguish between the two long-distance train product ICB and ICE, if this distinction is appropriate. Furthermore, the questions differ in length. Due to the semi-structured type of interview, multiple choice questions are not included. The presented sub questions (alternatives per answer) might suggest this, though these are meant to help the interviewer.

In general, the participants are free to answer in any way they want. There are no right or wrong answers. Furthermore, the project plan is not handed over to the participants. In this way an unstructured conversation is possible with the advantages mentioned earlier. The core question number 7, refers to the ranges found in literature (see Table 3-6), which consists of 18 elasticity ranges. In order to diminish misunderstandings by explaining the ranges, the table is sent shortly before the phone call or handed over during the interview. In this way all participants have the values visible during the interview. The participants are asked to give an indication (number), where according to their opinion the elasticities for the Dutch-German long-distance market are close to. Given the ranges, the participants have a bandwidth to choose from. One might argue, that this influences the participant's answers.

Another approach is to let the experts fill in values, without providing any indication. This would lead to unaffected answers, which suggest a higher reliability. However, there are two reasons against it. First, the field of train demand modelling is small. Only four exerts are found to participate in this study. Second, the amount of 18 values asked, is high. As elasticity values indicate the demand changes, they are an important way to evaluate services in an economic way. This type of information is confidential to companies. For international as well as international projects, companies aim to share as least sensitive information as possible in order to avoid advantages for competitors. Especially the last reason leads to the conclusion that the participants prefer to give approximations, rather than fill in a table with in total 18 values.

3.4.4 Interview means and approval

As the interview is semi-structured, it is conducted either face to face or by phone call, if the first is not possible. In order for the interviewer to guide the conversation rather than make notes, the interviews are recorded, if the participant agreed on it. After the approval of answers by each interviewee the records are deleted. Besides a phone for recording or calling purposes, a pen and paper was used.

The experts 1, 2, 3, and 4 received the entire interview plan to approve their answers. This step contributes to the transparency of interview and information derived from it. In case the participant does not agree on one or more answers as summarized by the interviewer, he or she might make remarks. As there are no right or wrong responses, answers may not be corrected only remarks given.

By incorporating all remarks the participants agree on the answers given as printed in Appendix B.

3.4.5 Outcomes interview

In this sub section, the answers are summarized based on the semi-structured interview on the international passenger market Netherlands-Germany. Appendix B shows the approved answers given per expert. As all four interview-participants shall remain anonymous, names are not mentioned. In order to make the outcomes more readable, the experts are referred with "he".

Question 1 – Growth factor

The interview starts with a question about the expected growth rate of the Dutch-German market. This is a question independent from elasticities, rather straight forward to answer and thus chosen as introduction to the topic. Furthermore, the question refers to insight gained earlier in section 3.3. Using a question, which answer is known, helps to test the experts knowledge about the market or his ability to transfer knowledge to other markets. The growth factor is asked for the market in general but with the indication that the growth for both products, the ICB and ICE might differ.

Expert 1 explains that the national model does not include the international market. For the national market, which is comparable to the ones in the international setting, a constant annual growth for the coming years of 2% is assumed. According to him, the markets mainly differ in the mix of trip purposes. Hence, the value for the NL-DE market should be different but comparable to the national one. Expert 2 gives a similar line of reasoning. Furthermore, he mentions that the ICB is slower and thus has more potential to grow than the ICE. This is also reasoned by the attractiveness as destination compared to the ICE. Equal to the first two explanations, expert 3 refers to the national model. However, the model he uses, shows rather conservative growth factors. For the NL-DE market, he expects higher growth rates (see Table 3-7, note 3) up to 1%. Expert 4 answers briefly with less than 1% growth. However, he mentions not to know the market very well.

Question 1 results in growth rates for the Dutch-German market of about 1% to 2%, which are in line with the assumptions mentioned in section 3.1.2. (forecast 2024). The results are summarised in Table 3-7.

Table 3-7: Answers for question 1 – growth factor.

	Expert 1	Note 1	Expert 2	Note 2	Expert 3	Note 3	Expert 4	Note 4	Final
Question 1.	2%		2%		0.50%	+	1%	-	~1-2%

Question 2 – Short, cross-border vs. long, domestic

In the second question, the lack of literature on long-distance and cross-border studies is presented. However, there are studies on short-distance trips across the border or domestic long-distance trips. Distinguishing these two types of market, the experts are asked to choose the one, which is the most comparable with the Dutch-German one. Without exception, all experts consider domestic but long-distance markets as the most comparable one (see Table 3-8). Or in other words, long-distance trips differ from short distance trips in terms of trip purpose. The availability of a border plays a minor role.

Table 3-8: Answers question 2 – Short, cross-border vs. long, domestic.

	Expert 1	Note 1	Expert 2	Note 2	Expert 3	Note 3	Expert 4	Note 4	Final
Question 2.	long		long		long		long		long

Question 3 – Border penalty

Question 3 is strongly related to question 2 and incorporates the cross-border barriers. (Knowles & Matthiessen, 2009) describe that demand forecasts for international rail and road projects are often inaccurate due to the reduced demand when crossing a border. However, the experts 1, 2 and 3 clearly state that for the

NL-DE market, this effect can be neglected. Mainly they reason this with the trip purpose. All four experts think about the ICB as a, mainly leisure passenger carrying line. But also the ICE, which they assume to have a higher business passenger share, will not significantly suffer under the fact that a border separates the two countries. Expert 4 first mentions border penalties, which are added to the total travel time. However, after is asked to quantify these, he reconsiders his answer and explains that eventually for long-distances trips these might be so small that they can be neglected.

Table 3-9: Answers question 3 - Border penalty.

	Expert 1	Note 1	Expert 2	Note 2	Expert 3	Note 3	Expert 4	Note 4	Final
Question 3.	no		no		no		minimum		no

Question 4 – Business (B) vs. Non-Business (NB)

In contrast to question 1 to 3, which deal in general with the NL-DE market, question 4 opens the elasticity related part of the study. Similar to question 1, question 4 seeks to introduce the topic smoothly to the experts. In section 3.3.1 the general findings of transport attributes in relation to the trip purposes business and non-business are presented[8]. Question 4 hence asks which traveller type is more sensitive to the three service attributes, frequency, fares and travel time.

Independently asked, the experts all agree that business passengers are more sensitive to travel time related attributes than non-business passengers (answer a.). For fare related attributes, the sensitivity is the other way around. Passengers travelling for leisure pay more attention to price related factors (answer b.). According to the sequence of service attributes asked (frequency, fare, travel time), the answer are given with a, b, a. This is in line with the findings from literature.

Table 3-10: Answers question 4 – Business (B) vs. Non-Business (NB).

	Expert 1	Note 1	Expert 2	Note 2	Expert 3	Note 3	Expert 4	Note 4	Final
Question 4.	a.b.a		a.b.a		a.b.a		a.b.a		a.b.a

Question 5 – Competing modes.

Cross-elasticities help the modeller to understand interrelation between competing modes. For the train service to Germany the competing modes are car, air and bus services (see section 3.1.3). There are two types of cross-elasticities namely, the train demand change, when changing the service attributes of a competing mode (e.g. congestion on freeways) and the demand changes of other modes, when changing the train service. For this study the latter is closer examined. This is mainly caused by the assumption that an improved train service reduces external effects and thus provides an interesting insight for political stakeholders.

As section 3.1.3 shows, the modal split differs per train service. For this reason question 5 distinguishes between ICE and ICB. The experts are asked to give their opinion about competing modes, which incorporates the modes in general and give a ranking among them. Due to the fact that the cross-elasticities found in literature are derived from MNL models, the values are the same for all competing modes. As explained in section 3.2.2 (limitations) this is a shortage of the MNL. A differentiation among the values is desired. E.g. given a mode share of 31% (train), 19% (airplane), 38% (car) and 12% (bus) for the ICB, the number of passengers swopping from train to car, is expected to be higher than to airplane. The bus will be chosen by the fewest amount of passengers. Question 5 thus encourages the experts to predefine a ranking of modalities, which might be used for question 7.

In order to answer this question, the experts define decisive factors for mode choice. Some experts refer to only one or two mode, which they consider as most competing with train. For expert 1 travel costs and travel time play the biggest role, when choosing a mode. However, also mode preference and car availability play a

[8] In the mentioned chapter as well as in appendix (interviews), the definition of business and non-business passengers is given, as used for this study.

role. Expert 2, uses similar to expert 1, time and money components of services, to make a ranking among the modes. Expert 3 uses the distance to make a mode selection. He defines for shorter distances the car as most interesting. However, with an increase in travel distance the attractiveness of airplane increases. Travel time and distance are equally mentioned by expert 4. However, for the ICE no ranking is given, as he is not certain about the trip purpose composition.

From question 5 follows that the experts assume for distances similar to the Amsterdam-Frankfurt ICE service, the highest competition with car. For longer distances (ICB) the airplane attractiveness increases. Whether or not busses play a role, is determined by the trip purpose and traveller characteristics. Passengers with low money budgets and high travel time budgets do opt for the bus. However, the Amsterdam-Frankfurt connection is assumed to be highly demanded by business passengers.

Table 3-11: Answers question 5 – competing modes.

Question 5.	Expert 1	Note 1	Expert 2	Note 2	Expert 3	Note 3	Expert 4	Note 4	Final
ICE	car		car, air		car		car		car
ICB	air, bus		air, car, bus		air		air, car, bus		air

Question 6 – Short vs. long-distance elasticities.

This question aims to provide more insight into the absolute values of elasticities. There is more literature found on urban elasticities, with trips up to 25 kilometres, than on long-distance elasticities. Question 6 seeks to provide an idea, whether short distance elasticities are higher, the same or lower compared to long-distance elasticities. With a better understanding of this relation, a derivation from short distance elasticities becomes possible.

Expert 1 mainly refers to two aspects when formulating his answer. First, the available alternatives a traveller has and second, the type of traveller. The expert explains that travellers with an available alternative are more sensitive, than passengers without. For short distance trips this would be mainly the car, however, for long-distance trips the airplane is often considered. Furthermore, frequent travellers will be more sensitive to, e.g. travel time changes, than occasional travellers, as the latter has less reference experience. Summarizing these increasing and decreasing sensitivities and given the fact that the expert has no deeper insight into the market, he assumes similar sensitivities for both, short and long-distance trips (answer C). Expert 2 assumes that long-distance elasticities are higher than short distance ones (answer A). He reasons this with an additional mode, which becomes available. Furthermore, he adds that a 10% decrease in travel time, has a higher impact on long-distance than short distance trips. Therefore, in conclusion long-distance elasticities are higher than short distance elasticities (answer A). A similar justification give the remaining two experts. Expert 3 however defines his answer per service attributes. According to him, travel time elasticity increases the most, with an increase in distance. The fare elasticity increases as well but to a lower amount. The frequency for long-distance trips is lower than for short distance trips due to demand. Doubling the frequency in both case might lead to similar effects. Thus his answer is A and C for frequencies.

Question 6 intended to state a relation between short and long-distance elasticities, as the first is often investigated in literature. Three out of four experts stated the dependency of elasticity values on distances.

Table 3-12: Answers question 6 - Short vs. long-distance elasticities.

	Expert 1	Note 1	Expert 2	Note 2	Expert 3	Note 3	Expert 4	Note 4	Final
Question 6.	C		A		A		A+C		-

Question 7 – Demand elasticities for the Dutch-German market.

With the final question, elasticities resulting from literature are evaluated. Although the literature review used an assessment framework with five criteria to exclude not relevant studies (presented in chapter … el review), the found elasticity values show two issues.

- For some service attributes wide ranges appear.
- For others only one or no values are found.

As none of the reviewed studies is subject to the Dutch-German long-distance market, the expert opinion is required. Before answering question 7, each expert received Table 3-6 (section 3.3.4), which includes the elasticity ranges. All experts are asked to give a value between the ranges, and of which they think is the most appropriate for the Dutch-German market. In order to make the answers comparable, earlier mentioned table is translated into to following table … , where each cell receives an own ID.

Table 3-13: Cell ID's.

From MNL resulting elasticities when changing rail service attributes.						
Rail service attributes	**Train**		**Air (cross-elasticity)**		**Car (cross-elasticity)**	
	Business	**Non-Business**	**Business**	**Non-Business**	**Business**	**Non-Business**
Travel Time	7.1	7.2	7.3	7.4	7.5	7.6
Fares	7.7	7.8	7.9	7.10	7.11	7.12
Frequency	7.13	7.14	7.15	7.16	7.17	7.18
7.x	The first nr. refers to question 7.					
	The second nr. (x) refers to cell number in table.					

Number 7 refers to the question. The right number represents the cell. All experts are asked to give an indication about the Dutch-German elasticities, within the ranges. In the following Table 3-14, the answers are listed, using the ID's from Table 3-13, column "ID". Right aside, column "ranges" shows the elasticity ranges found in literature. The answers given by the experts are shown in column "expert". Every expert is indicated with the number and a unique symbol, which will be used later in .

Some of the experts preferred to give an approximation instead of mentioning one exact value. These values are presented with superscript characters, explained in the legend. With different nuances of grey the different modes are represented. Train and thus direct demand elasticities are displayed with the darkest colour.

Table 3-14: Answers question 7 - Demand elasticities for the Dutch-German market.

ID	Range	Expert 1 [#]	Expert 2 [$]	Expert 3 [o]	Expert 4 [^]
7.1	-0.6 to -1.8	-1	-0.6	-1.2 (m)	-1 (+)
7.2	-0.2 to -0.4	-0.3	-0.3	**-0.6** (+)	-1 (--)
7.3	+0.4 to +1.3	0.9			
7.4	+0.5 to +1.6	0.6			
7.5	+0.4*	0.4			
7.6	**	0.2			
7.7	-0.6 to -2.0	-0.6	**-0.3**	-0.6 (+)	**-0.4** (-)
7.8	-0.6 to -1.1	-0.9	-0.9	-0.6 (m)	-1 (-)
7.9	+0.3 to +0.5	0.3			
7.1	+0.1*	0.1			
7.11	+0.1 to +0.5	0.5			
7.12	+0.3*	0.3			
7.13	+0.3 to +0.6	0.4	0.4	0.3 (+)	0.4 (-)
7.14	+0.1 to +0.2	0.15	0.1	0.15 (m)	0.4 (--)
7.15	-0.1 to -0.7	-0.2			
7.16	-0.1 to -0.6	-0.4			
7.17	-0.1*	-0.1			
7.18	**	-0.1			

Legend

(+)	(relatively) higher as left value (colomn range)
(++)	(relatively) significantly higher as left value (colomn range)
(m)	in the middle of the range
(-)	(relatively) lower as left value (colomn range)
(--)	(relatively) significantly lower as left value (colomn range)
*	for this elasticity only one reference value is found
**	for this elasticity no reference value is found

Looking at the combined answers of all experts one realises, that only expert 1 gives an answer to all values (column expert 1). Although he states upfront that he is not fully aware of the market characteristics, as mode shares and trip purposes, he fills in all gaps. However, the participant uses averages only for the non-business travel time (row 7.2) and frequency (7.14). For the remaining 16 values, his answers stay within the ranges. Furthermore, from elasticity values composed by one study only (indicated with "*") the expert does not deviate. For the car cross-elasticities, he indicates conservative, low values. This is in line with answer 5, where the expert states the highest competition between rail and air. For the fare cross-elasticity, which is equally by all experts assumed to be higher for non-business passengers than business (answer 4), the cross-elasticity for car is higher (7.11 and 7.12). This represent the expert's line of reasoning in question 5. There he explains that train competes with train the most under the condition that both have similar prices (see also expert 1 interview answers Appendix B).

Expert 2 indicates direct demand elasticities only. As he has not enough insight into the absolute mode shares for the two lines, he suggests a proportional distribution of the train-leaving passengers towards other modes (see Appendix B expert 2 answers). For changes in train travel time and train frequency, he assumes a proportional distribution of 20/80/0 for air/car/bus. As for fare changes people with low budgets are sensitive, the expert assumes a willingness to travel with low budget busses. Given this relation, he states a proportional distribution of leaving train passengers of 10/50/40. Using this, the participant gives no elasticity values but an indication of proportions to calculate cross-elasticities. Moreover, expert 2 presents a value (bold number) for fare elasticity (7.7), lower than the range suggests (bold number).

The third expert is a specialist in long-distance demand modelling from 50 km onwards. Due to confidentiality, reasons exert 3 rejects to give exact values. However, based on the national market analysis the expert gives an indication on their used elasticities. For this reason, he uses the ranges as relative intervals. A value of -1.8 in his reasoning is thus higher than a value of -0.6. Furthermore, he splits the interval in three areas, upper, middle and lower bound. These are indicated with a plus sign (+), the letter (m) and a minus sign (-). If the expert refers to the upper or lower bound, he implies a value within the interval. For answer 7.7 for instance, the expert refers to the lower bound of 0.6. This can be either 0.6 or higher (indicated with +), but not outside the range. In cases his answer suggest a value outside the range (see question 7.2), he adds the information "out of the interval, but within the lower bound of business". For the elasticities 7.1, 7.8 and 7.14, he states "in the middle", which might be both, above and below average. In conclusion, the expert diminishes the ranges by indicating smaller ranges.

For the cross-elasticities expert 3 uses a MNL. As no shares for the remaining modes are given, the expert is not able to state a cross-elasticity. However, close to the explanation of expert 2, he uses mode shares, to indicate the demand distribution.

Similar to expert 3, expert 4 gives no exact values. He uses per elasticity type a reference value and adds remarks as "more", "less", "way more" or "way less" to indicate the elasticity. In answer 7.1 and 7.2 for instance he states -1.0 as reference value. For business passengers he suggests this value slight higher indicated with a plus (in absolute terms), for non-business the value is supposed to be way smaller (--). Similar to expert 2, expert 4 assumes a fare elasticity for business passengers (7.7) smaller than suggested by the range. Therefore, the value is illustrated bold. For the cross-elasticities, the expert is more familiar with cross-elasticities of type 2. Thus, the percentage change of train demand, when service attributes of competing modes change. Especially in the models used by him, he is interested in the relation travel time car and demand changes train. For the frequency elasticity expert 4 mentions an important difference compared to the other two elasticities. When talking about frequency the changes are often bigger than 10%. Doubling frequency from one time, to two times per hour, results in a waiting time shortage from 30 to 15 minutes. In conclusion double frequency means a 100% increase in service. For this doubling effect, the expert uses an increase in train demand of one third for short distances. On long-distance trips this effect is assumed to be less. This stands in contrast to expert 3, who assumes equal effects for both, short and long-distance frequencies (see answers question 6).

Finally, the direct demand elasticities given by the experts are summarized in the following Figure 3-10. The red bars illustrate ranges. Each symbol represents one expert. The symbols are the same as written in square brackets in the previous table (expert column). Expert 3 states ranges only. As no further insights are available, his answers are considered conservatively. Thus, if he refers to the lower bound, the lowest value is chosen. For the demand means this the lowest growth in case of improved train service. On the other hand, in case the service get worse, the demand decreases on a low scale. However, as this study aims, to improve an existing service (case ICB), the values are treat conservatively towards growing aspects. For elasticity indications in the middle of an interval, simply the average is used. Tests show, increasing them by one to three tenths results in minor changes for the overall values (explained later in text). For the indication given by expert 4, the plus and minuses are used to adjust the values by either one (-) or two (--) tenth.

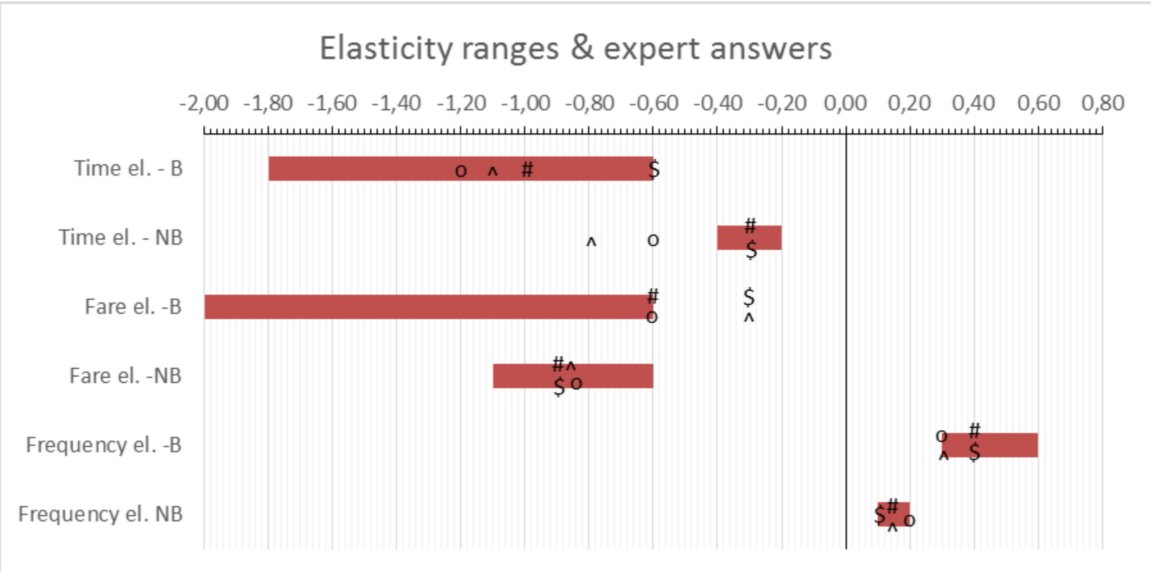


Figure 3-10: Elasticities ranges and expert answers.

For travel time elasticity business, the experts diminish the range by a half (-0.6 to -1.2). On the other hand, the range increases for the non-business time elasticity (-0.3 to -0.8) as experts 3 and 4 give state higher values. Equally, the fare elasticity range for business passengers seem to be higher, than the experts suggest for the Dutch-German market. Nevertheless, looking at the last three elasticities, the experts state similar values within the given ranges.

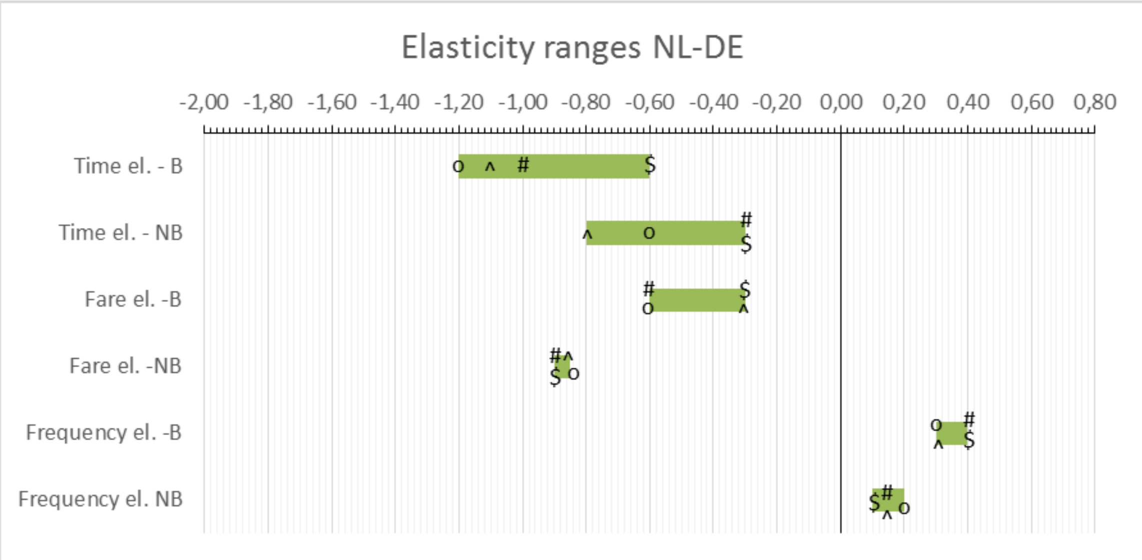


Figure 3-11: Resulting elasticity ranges NL-DE.

3.4.6 Cross-elasticity calculation

In order to determine cross-elasticities for the Dutch-German market, mode shares need to be known. These vary per OD pair. Furthermore, cross-elasticities result from logit models but may vary dependent model type. For the Dutch-German market complete OD data is available for the following OD pairs:

- Amsterdam-Berlin (ICB)
- Amsterdam-Frankfurt (ICE)
- Amsterdam-Köln (ICE)

Based on the direct demand elasticities for train and the mode shares, the cross-elasticities are calculated using four steps:

First, with the known mode shares, the number of passengers per mode are calculated.

Second, a threshold is set for train passengers that cancel their trip after a service change (expert 2 suggests 25%). This is done to make the relations more realistic. In case this threshold is not implemented, the diverting passengers redistribute entirely over the remaining modes.

Third, the remaining 75 percent of passengers leaving the train opt for an alternative. These passengers are distributed over the remaining modes according to their shares.

Fourth, with the increase in passengers on the alternative modes, the percentage change is determined.

3.4.7 Reflection on interview outcomes

For the questions 2 to 4 all experts give similar answers. As the first questions are meant to introduce the participant to the topic of Dutch-German elasticities, the similarity in answers is considered appropriate. Previous tests with colleagues and friends however showed that also people without knowledge on train demand modelling are able to come up with the same answers. However, given the insight of test interviews, the line of reasoning plays an important role. Although two out of four experts are not working with international demand models on a regular basis, they give a similar line of reasoning. Regardless if the experts refer to the national or international model, they use comparable approaches to determine parameters of their model. For the growth factor of question 1 for instance, each expert refers to the economic growth as external factor, which they incorporate in their models. This is also in line with approaches found in literature (PDFH B, 2009). For answers given on question 2, 3 and 4 similar is observed.

Question 3 reveals in an interesting outcome. For long-distance trips as done with the ICB and ICE, the experts state that border penalties can be neglected. According to Rietveld (2012), borders do represent barriers, which are often underestimated when evaluating new transport projects. In fact, the authors state that demand decreases in the direction of the border and beyond it. This implies that domestic projects reveal higher benefits that international ones. This is especially true for new projects. However, the here presented elasticities refer to changes of existing services, where the demand is known. For this reason border barriers or penalties are neglected. The eliminated border controls in Europe, as well as the common currency are some additional reasons, why border penalties tend to decrease.

Question 5 refers to the competing modes, which are supposed to help the experts later when indicating cross-elasticities (question 7). During the time the interview was hold, the current mode shares were not available. One might argue that the availability of mode shares on the Dutch-German market, leads to more precise answers regarding cross-elasticities. However, in this way the experts are influenced by the information given. On the other hand, missing information forces the experts to explain the way how cross-elasticities are calculated rather than exact values. The reaction on cross-elasticities revealed in two interesting insights. First, the experts not applying cross-elasticities in their models, are not exactly aware how these need to be calculated. Furthermore, it is crucial to define, on which changes the regarded cross-elasticity depend. Type A indicates the changes in demand for train, if service attributes of modality k change. Type B in contrast, reveals in demand changes in modality k, if train service changes. Whereas expert 3 is aware of both types and their expected values, uses expert 4 type A only, and expert 1 and 2 none of them. Hence, regarding the information amount given to the interviewees upon front, it is preferred to reduce it to a minimum. In this way the type of interview (semi-structured) is used advantageously as an active discussion results. This helps both, the experts to understand the question better but also the interviewer to understand, where the leaks more insight.

The experts are mainly chosen due to their experience with train demand models. The four experts work at three different companies located in three different European markets. They all have work experiences from eight years and more. Although only two experts work with models including international traffic, the experts derive similar answers from their knowledge as presented in section 3.4.5. Bearing in mind that two experts do not work with international models, question 6 is formulated. Here a relation between short and long-distance elasticities is asked. Expert 1 is the only one, answering differently. Furthermore, expert 1 is the only one indicating cross-elasticities values, which actually requires the knowledge about mode shares for this market. Whether he assumes similar mode shares for the Dutch-German market than on the national market is not clear. However, already during question 1, the experts states that he misses an extensive insight into the market. Thus, his answers regarding cross-elasticity cannot be used for the Dutch-German market. The remaining three experts relate cross-elasticities to the mode shares on one hand and refer to the limitations when using elasticities on the other hand. This insight is qualitative but useful in order to quantify the final cross-elasticities.

Overall it is highlighted that this interview reveals in no significant outcomes, as the number of participants is too small. Nevertheless, train demand modelling is mainly applied by train operators. Until today, international train transport (long-distance) is provided by a limited number of operators, which are former national companies. Finding ten independent experts might hence result in experts from ten countries. However, these most likely will not have the desired knowledge of the market characteristics. Furthermore, it is highlighted that efforts were made to find experts from other institutions. However, they rejected the participation in this interview due to a limited expertise.

In conclusion, the few experts diminish the found ranges from literature. Furthermore, the semi-structured interview enabled further questions to get a better understanding of the elasticity and cross-elasticity calculations. Overall the interview outcomes result in useful insights and input for further investigations.

3.5 Conclusions - Demand side

This chapter analyses the Dutch-German market or, according to the theoretical framework (section 1.5.1), the demand and demand parameters. As two parts of the framework are included, the chapter is subdivided. First, the outcomes of the transport demand section are presented. The remaining sections provide an answer to the second sub research question.

TRANSPORT DEMAND

From the analysis of the international matrices 2014 and mode shares, the following aspects are concluded for both services between the Netherlands and Germany (ICB and ICE):

- The international train demand is split in 1/3 IC and 2/3 ICE.
- IC Berlin passenger composition: Around 1/3 are domestic and 2/3 international passengers. The majority of both traveller groups travels for leisure purposes. One fourth of the national passengers uses the IC Berlin for business or commuting trips.
- The top-10 access/egress stations cover between 70% and 80% of all train demand. Since also secondary stations (stations not located at line, as e.g. Rotterdam or Hamburg) are among the top-10 stations, the services do not cover the main OD-pairs.
- Amsterdam is the most important access/egress station for international train passengers (strongest OD-pairs). In Germany, the stations Berlin, Düsseldorf and Frankfurt show comparable attractions/productions. Köln-Amsterdam is the thickest OD-pair with more than 5%.
- For the cities Köln, Frankfurt, Berlin, the train provides a constant share of around 30%. The highest mode share has car, which decreases with an increasing distance. Air demand is the highest for Frankfurt and Berlin. The long-distance bus market accomplishes about 10%.

These insights explain the current situation. With the growth factor method, the demand for 2024 is calculated. However, in order to be able to forecast demand changes, when adjusting the future service, the following sub research question is stated.

Which demand parameters are required to model demand behaviour for the Dutch-German market?

In order to provide an answer, the question is divided in two parts. The first considers train demand modelling in general.

a) How can demand behaviour be modelled?

Literature on transport modelling distinguishes between multistage and direct demand models. The first, also called 4-step model, requires an extensive amount of input data, as sub models need to be created. The direct demand model in contrast, avoids the sequential methodology and determines directly demand changes. In practice however, the elasticity model is used (a quasi-direct demand model). The main advantages and disadvantages are summarised in the following table.

Model	Pro	Con
Multi-stage	• Applicable for modelling new services, infrastructure, etc. • Due to many constraints calculations rather easy.	• Needs much input data. • Time intense.
Direct demand	• Easy to apply for smaller changes in service. • Shows for inter-urban transport forecasts better results.	• Demand function is unconstraint and thus difficult to approximate.
Elasticity	• Easy to apply for smaller changes in service.	• Requires knowledge on demand behaviour (demand elasticities).

	• Used in practice.	• The use of elasticities is limited.

The elasticities are demand parameters, which describe passenger behaviour in relation to a given set of constraints. The constraints are distinguished between exogenous (income, car ownership, etc.), and endogenous attributes (frequency, travel time, costs, etc.). In countries as the UK, Switzerland, Germany and the Netherlands, train demand is modelled using elasticities. Over the years, operators gained insight into the demand behaviour. Based on this historic data, they update the used elasticities every year.

Nevertheless, the use of elasticities is limited to the following applications:

- Small changes – Demand behaves not linear but in a curve. However, for every item, the curve has a different shape. As demand elasticities represent a point or arc on this curve, the effect of major impacts cannot be modelled. In this case, the use of a 4-step model is recommended. However, it is highlighted that there are no exact thresholds found. One reason could be the wide ranges of applications of elasticities. Thus, the increase in frequency for instance is different from the decrease in fare. Therefore, the word "small" is difficult to define.
- Existing service – Elasticities are based on existing correlations between supply and demand. Since new services provide no supply reference, the correlated demand is unknown. In this situation, elasticities are not applicable. An example of a new service is the introduction of a toll system.
- Aggregated representation – Demand elasticities indicate whether demand increases/decreases (elastic demand), or stays rather unchanged (inelastic demand). However, they do not distinguish for instance between certain zones. Thus, the demand increase or decrease is a global approximation.
- Ceteris paribus condition – The demand parameter (elasticity) holds only, if the remaining services are constant. Thus, the fare elasticity for instance is only applicable, if the fares of competing modes remain unchanged. In case of a unimodal model, ceteris paribus holds for the service attributes. Hence, the fare elasticity holds only, if the other service attributes (frequency, travel time, tec.) remain constant.

In conclusion, train demand can be modelled by using either multistage or direct demand models. In case train demand behaviour shall be forecasted (for existing services only), an elasticity model can be used. However, in order to apply an elasticity model the demand parameters, or demand elasticity values need to be known, which leads to the second part of this question:

b) What are the demand parameters for the Dutch-German market?

In order to answer this part of the sub research question, literature on train demand and mode choice is reviewed. However, due to the nature of elasticities to provide aggregated demand volumes based on a certain set of constraints (distance, purpose, etc.), the found elasticities need to be treated critically. In order to find relevant parameters for the Dutch-German market, a literature framework is established. The framework lists five criteria, as distance, studies country etc., which are found relevant for the considered market. From the selected literature, high ranges of elasticities result. Therefore, the found elasticities are presented to experts. In a semi-structured interview four experts, from three different countries are asked on their opinion. From the literature study, the following insights are gained:

1. In literature, mostly two groups of passengers are distinguished, namely business, and non-business.
2. There is little investigated on the cross-elasticities for car and train use. The most recent studies compare HSR and air transportation.

3. Demand behaves differently on service improvements, than service worsening in short-term perspectives. In a long-term consideration, the effects should be symmetric. However, there is not enough research done on long-term effects.
4. Business passengers are more sensitive to time related attributes. Non-business passengers to money related attributes.

From the expert interviews further insights are gained:

1. The expected annual growth for the Dutch-German market is between 0.5 and 2 percent.
2. The cross-border effects for the Dutch-German market can be neglected, when travelling long-distance.
3. The travel time elasticity increases with increasing distance travelled.
4. Cross-elasticities depend on the available mode shares.

From this investigation, the final demand parameters for the long-distance transport market Netherlands-Germany are concluded. The outcomes from the expert interviews, as well as the calculated cross-elasticities are presented in Figure 3-12. The table shows, how business (B) and non-business (NB) passengers react on changes in service.

	Train		Air		Car	
Rail service attributes	Business (B)	Non-Business (NB)	Business (B)	Non-Business (NB)	Business (B)	Non-Business (NB)
Travel Time	**-1.0**	**-0.6**	0.3	0.1	0.3	0.1
Fares	**-0.5**	**-0.8**	0.2	0.2	0.2	0.2
Frequency	**+0.4**	**+0.2**	-0.1	-0.1	-0.1	-0.1

Figure 3-12: Direct and cross-demand elasticities for the Dutch-German market.

The found elasticities need to be treated critically. There are two aspects, which should be bared in mind:

1. Elasticities depend on the market characteristics (exogenous and endogenous factors).
2. A small group of experts applies elasticities.

The wide range of values found in literature indicates the difficulty, when using elasticities. As the values provide demand behaviour for a dedicated market, they differ per study. In addition, the number of interviewed experts is very low. For future investigations, more experts are preferred. However, it is highlighted that a small group of experts performs train demand modelling. The absolute values are close related to the market. Therefore, experts modelling on comparable markets as the Dutch-German long-distance market, are adequate participants for interviews.

Despite the group of experts, it is highlighted that the type of interview and questions have no statistical significance. The answers are purely based on the expert's knowledge. Thus, over- or underestimated values might be the case.

Furthermore, the presented values are averages of the answers given by the experts. Some experts provided again only approximated values, rather the accurate numbers. Nevertheless, the experts' opinion is beneficial, as it helped to smaller down the literature findings. Overall, the literature as well as expert opinions help to find the elasticity values, which are the answer to the previously formulated sub research question.

PART B

4 Modelling alternatives

The insight gained from chapter 2 (supply side) and chapter 3 (demand and parameters), represent the INPUT required for the modelling step. This chapter starts with the description of the methodology, which consists of (A) the determination of alternatives and (B) the quantification of alternatives. In the second section, the alternatives are determined with the use of the relevance tree and translated into real measure applicable for the IC Berlin. The different alternatives are then tested with an international model, which we established for this research. The required steps to obtain such model, the model limitations as well as the model validation are part of section 4.3. The chapter ends with the sub conclusions from this modelling step and the answer to the third sub research question.

4.1 Methodology

For the intercity Berlin, service alternatives shall be found. Changing a single attribute of the current intercity service, results in an alternative. In this way there are many combinations of variables and thus new alternatives possible. The first goal of this chapter is to determine alternatives in a structured way. The second part of this chapter seeks to test the different alternatives found. A model is established to quantify the alternatives and enable a comparison. The model uses an objective function to find an optimum line alignment, within the Dutch-German network. The optimum is found using a number of parameters, among others the elasticities determined in chapter 3. The current chapter is hence split into two parts:

A. Determination of alternatives
B. Quantification of alternatives

Within the possibilities of a new service between Amsterdam and Berlin (or any other origin destination pair), there are multiple aspects of the service which might be changed. Fares, faster vehicles or even punctuality are a few examples. The aspects, measures or adjustments are in the following text described as *variables* of the railway line (system). In general, the variables shall help to improve the current service. Whether an improvement is found or not, is described by objectives, which vary across stakeholders. Passengers might perceive directness as the most important objective, whereas operators might consider the minimisation of costs as the highest goal. These goals might be contradicting in realisation. A brief literature study is conducted to illustrate the differences between objectives. Finally, one objective function is chosen for the next steps.

Due to the amount of variables a structured approach is required. An illustrative example is presented by Ross (2001), who investigated the economic performance of Deutsche Bahn. With a "Relevanzbaum", in this study called *relevance tree*, he structures the search area and determines later planning strategies, following DB's objective to maximise profit. The approach originates from Hans-Christian Pfohl, who describes the *relevance* tree as a decision tool. This method enables the user to categorize measurements (variables) on one hand and shows interdependencies on the other hand. In the first section (A) the framework is applied to find, and illustrate possible alternatives for the IC Berlin. However, the tool is applicable for any other train service.

After the determination of alternatives, their effectiveness needs to be tested. This is done using the NS tool "Lijnvoeringsmodel" (LVM). The model is based on a genetic algorithm and seeks to optimise the lines within the Dutch network. Niek Guis contributed with his graduation work mainly to the current version of the LVM, as he provided insight into the genetic algorithm. The optimisation follows commercial needs, since it seeks to maximize profit. However, the overall objective is achieved, following different sub objectives.

This is in line with the objective used in the relevance tree. By inserting the network, the demand for 2024, as well as parameters, the model is useful in two ways. First, the alternatives determined with the relevance tree can be modelled and their impacts quantified. Secondly, using the genetic algorithm, the model can optimise the provided service lines, given the demand (revenues) and needed means (costs). Both properties of the model are used and explained in section 4.3. As the current model is designed for the national network only, different modifications of it are required.

4.2 Determination of alternatives – (A)

The different measurements are structured to alternatives using the relevance tree from Ross (2001). For the intercity Berlin, the set of possible measurements will be narrowed down to the ones "relevant" for this line. From these, four alternatives are derived.

4.2.1 Objective functions for public transport

The choice on an objective function depends on the research purpose or the party, the research is conducted for. (Nes, 2002) defines for public transports networks, three parties, namely the operator, the passenger and the authority. Each of the party has different interests and thus different objectives. Fulfilling them all is only to a limited extend possible, as they often lead to contradicting network designs. Using the three parties, the different objectives are described.

A passenger evaluates service by attributes as travel time, costs, comfort and service reliability. One of his interests is hence the perceived door-to-door travel time. With different perceptions within the time components the traveller weights elements of his journey as access-time, journey time, in-vehicle time, transfer time and egress time. The minimisation of these elements is hence his objective. In order to realize this objective the network needs to provide only direct lines. As the network consists of many nodes, which are not equal in demand, this objective would require many links, and would be thus very cost intense. For this reason a budget can be introduced. This budget limits the amount of new infrastructure. The traveller objective is finally summarized as:

Traveller objective = Minimization of perceived door-to-door travel time given a fixed budget.

In order to apply this objective function, the maximal budget needs to be known. This is difficult to determine as it directly relates to the operators financial possibilities. Furthermore, it suggests that the available budget will be spend. This however is in contrast to the operator's objective. As the majority of companies, operators seek to stay profitable. Their main interests is related to minimizing costs or maximizing profit. As minimizing costs, usually leads to less service and thus less travellers, the objective of maximizing profit is the desired:

Operator objective = Maximizing profit.

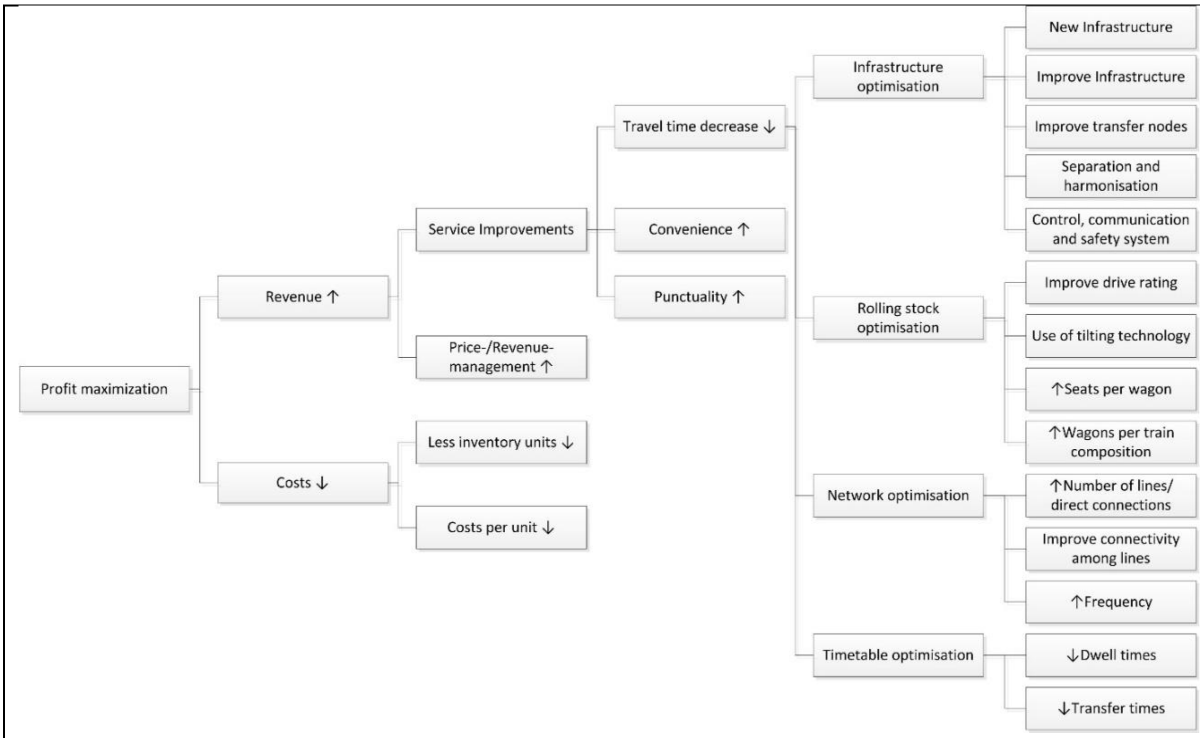
As a last party the authorities are listed. In public transport they play an important role, as they have the abilities to substitute operators and defend passenger interests. For international long-distance traffic the Dutch or German government are of less importance, as these projects are out of the national scope. In this case the EU provides support. With their budget from the Ten-T project for instance studies and realizations of cross-border projects are enabled (Groningen-Bremen). Authorities aim to find an optimum between the costs, an operator needs to spend and the maximum benefits for passengers. In literature, this is described as maximising social welfare, which is the sum of consumer and operator surplus. However, it is highlighted that social welfare incorporates also the costs and benefits for third parties, which are measured in externalities.

Objective for the international market = consumer surplus + producer surplus.

Nevertheless, optimising operators, travellers and authority objectives simultaneously, leads to a complex procedure. Social welfare is rather difficult to model due to the measure and thus in software models, as the for instance the LVM not incorporated. Therefore, it chosen to optimise in two steps. First, the operator's objectives are followed to determine alternatives and measures. In a later step, the alternatives are evaluated using a social cost benefit analysis. In this way it is not ensured to find the best solution, but within all solutions, the alternative will be chosen with the maximum social welfare.

4.2.2 Relevance tree

The relevance tree as used by Ross (2001), starts from the operator's objective of maximizing profit, as explained in the previous chapter. The entire tree is presented in Figure 4-1.



Objective	Aspects	Optimisations	Measures/ variables

Figure 4-1: Possible alternatives to maximise profit – relevance tree (Ross, 2001).

As shown in Figure 4-1, the commercial objective of maximising profit is achieved by either reducing costs or increasing revenue. The first mentioned, is achieved by decreasing the costs per unit or the reduction of inventory. Especially for companies with big fleets, the cost decrease per unit is an important issue. As explained in the chapter 2, the fleet of the IC Berlin is limited to a gross train sets number of twelve, which are used exclusively for the line Amsterdam-Berlin. Derived from the airline industry, where low budget carriers work with a standardized fleet, the costs per unit will decrease, if the fleet is insertable on other lines. In order to reduce the number of rolling stock, the travel time should be decreased. Given a fixed frequency, the turnaround time is then lowered and the same train can run another time.

In contrast to the cost decrease, the revenue increase is listed. As shown in Figure 4-1, there are two main mechanisms, namely the service improvement or the revenue management. Later implies, again similar to the airline industry incremental pricing strategies. Thus, the price increases stepwise, the closer the moment of departure approaches. Similar to the earlier mentioned cost decrease, pricing strategy relates to business economics. The service improvement as a counterpart is passenger interest oriented as it seeks to either decrease travel time, increase convenience or punctuality. The last two aspects are often investigated urban public transport as for instance (Balcombe et al., 2004).

For the travel time decrease, four optimizations are mentioned, which are divided in different measures. The first, infrastructure optimization, incorporates new infrastructure or improvements of existing infrastructure. At transfer stations, different lines cross. In order to provide a fast transfer from one line to another, the stations need to facilitate sufficient infrastructure to cope with the in- and outgoing rolling stock as well as the amount of arriving and departing passengers. Furthermore, the travel time can be reduced by assigning infrastructure to a single type of service, which is indicated in the box separation and harmonisation. One example is a dedicated high-speed line, where only trains with speeds above 250 km/h are running. The opposite is the harmonization, which allows the use of different services. For instance the mixed use of freight and passenger trains on the same part of infrastructure. As a last point under the infrastructure measures, the control, communication and safety system is mentioned. With the modernisation of the control and signalling system in infrastructure and vehicles (cabs), operational speeds can be increased.

The rolling stock optimization is mentioned as a second opportunity to lower travel time. With an improved engine power (driving rate), the acceleration can be performed faster. Furthermore, the overall operational speed is higher, as higher maximum speeds are achieved. A tilting technology is used in high-speed trains and enables trains to drive faster through curves. Related to capacity shortage, the optimization of rolling stock also implies the increase in seats per wagon or an increase of wagons per locomotive. With a higher capacity, the author assumes that the waiting time decreases for passengers, which lowers consequentially the travel time.

Furthermore, the optimization of the network is mentioned. Especially in a wide network as the German one, new lines or more direct lines improve the travel time. Furthermore, the connectivity among existing lines can be increased by for instance guiding lines over big transfer nodes. This leads to more travel options and thus, in total to a lower travel time. As a last, the frequency can be improved.

As a last point, the timetable optimization is mentioned. Here included are the decrease in dwell times or transfer times.

4.2.3 Relevant alternatives

In order to achieve the best result, the maximum number of optimisations need to be conducted. However, the number of optimisations and measurements vary per case. An intercity to Berlin for example, might face different service adjustments than a regional line shortly over the border or the City Night Line to Zurich. The services differ in their characteristics and thus for each line, the tree of relevant variables need to be established separately. The remaining tree indicates the resulting alternatives and is illustrated at the end of this section (Figure 4-2).

In a best case scenario, all available optimisations are incorporated within one optimisation: Maximise profit. This implies a multi-objective function, where infrastructure, rolling stock, network and timetable optimisation are optimised simultaneously. Besides the complexity of this mathematical problem, a practical disadvantage appears. Users do not understand the impact of a certain variables, when changing them. Furthermore, it is questionable how realistic it is to implement all measures. Hence, more desired are different alternatives (instead of one optimization), which comprise a set of comparable measures. Users are then able to understand which set of measures has a higher or lower impact on the total profit.

Within the optimisations not all variables are useful to incorporate for the intercity Berlin case. By excluding irrelevant measures, the final alternatives are obtained. In the following justifications are given why certain variables are considered to be irrelevant. The final alternatives consider measures on a strategic level. Operational details of execution are not considered at this stage.

Starting with the infrastructure measures, the improvement of transfer nodes is mentioned. With good working switches and enough capacity on a station, many transfers can be planned and transfer times decreased. Thus, transfer nodes play an important role for timetabling and station scheduling. At a strategic level the focus rather on the general service. For this reason, the transfer node improvements, as well as separation and harmonisation or communication and safety are excluded in the infrastructure alternative.

By improving the drive rate or using tilting technology the rolling stock can operate faster. As both variables eventually result in a higher averaged speed, they are summarised to one variable. Especially for the Dutch-German market the power supply differences play an important role. Eventually they lead to a waiting time at the border of about 10-15 minutes. This can be decreased by using multi-system locomotives. As it is a very important aspect for the IC Berlin, this variable is added to the set of variables. The last two rolling stock related issues consider capacity. In order to investigate the capacity needs, a detailed insight into demand is required. Seasonality, but also daily, weekly and monthly peak moments need to be known in order to make a comprehensive rolling stock planning. Again, this requires a detailed knowledge which is not given at this stage.

The variables mentioned for the network optimisation are especially interesting when optimising dense, urban networks. Increasing direct connections smooths daily transport. For the international network less lines are available, which leads to several travel time issues. First, the international lines operate on a rather low frequency. Waiting times are thus significantly higher, than for short distance trips. Second, demand for long-distance trips is lower than for short distance trips, as people are mostly not obliged to make a long-distance trip. For this reason it is not profitable to offer direct connections to all cities. As a last point, the connectivity between lines is mentioned, which is important for both types of trips, long and short distance. However, for the resulting network alternative, the variables are adjusted. With "change route", the dilemma is captured of demand vs. travel time. Another route as the current one may lead to longer travel times, but simultaneously could attract more people, which were not directly connected to the line before. "Change number of stops" refers to the travel time vs. stop density dilemma. Less stops lead to shorter travel times, which might generate demand. Simultaneously, less stops mean longer access and egress times for passengers, which used the train before.

Although the yield management does not relate to the travel time decrease, it affects the passenger demand and is thus interesting to investigate. Especially the IC Berlin carries recently an increasing amount of passengers, mainly for leisure purposes. As mentioned in chapter (elasticity), this passenger group is sensitive to price differences. In which amount an increase to decrease in fare affects the demand is investigated with the revenue alternative. It is highlighted that the alternative has a financial component, which could in theory also include the cost aspects. Nevertheless, the cost component is considered more relevant for the operator than for the passenger. An incorporation is therefore not considered.

Finally, by eliminating irrelevant measures (and optimisations) from the relevance tree, four alternatives are determined in their theoretical setting:

- Infrastructure
- Rolling stock
- Network
- Revenue

Sub section 4.2.4 elaborates on the resulting alternatives, by describing the real measures.

As a final step, an optimisation of costs and revenues will be conducted, which is explained in part (B) in more detail. The modified tree, including the relevant variables for the IC-Berlin as well as the final alternatives (dashed boxes) are presented in Figure 4-2.

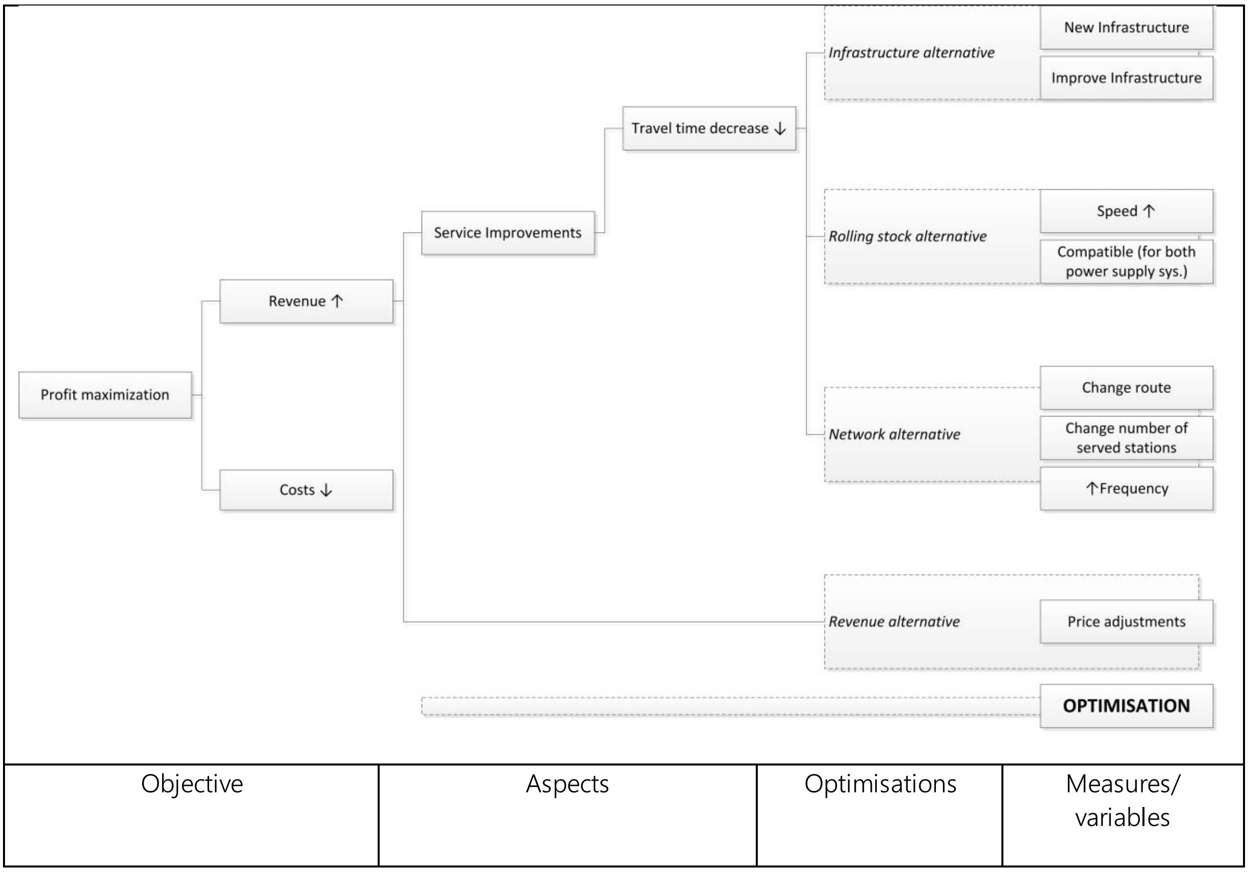


Figure 4-2: Resulting alternatives.

4.2.4 Resulting adjustments

With the relevance tree, the alternatives are pointed out. In a next step, these alternatives are translated into real measures, dedicated to improve the IC service to Berlin.

INFRASTRUCTURE ALTERNATIVE

As a first, the infrastructure alternative is described. For the realisation of new infrastructure two aspects are investigated. The first considers a new link. This is especially for connections interesting, which provide a detour in comparison with the crow fly length, and are expressed by the directness of a connection. As illustrated in Figure 2-3 (chapter 2), between both capitals exists a straight west-east connection. The total line is 625 km long (Deutsche Bahn, 2015), whereas the crow fly length is measured with 577 km ("Luftlinie.org," 2015). The quotient reveals in a directness of 92%, which is high compared to other international lines as for instance Amsterdam-London (59% = 608km/358km). A missing link thus, is not identified. However, the low average speed of the IC Berlin with 98 km/h does not provide an international connection, as identified by Nes (2000).

A solution will provide infrastructure, which enables the use of ICEs. The ICE3 is built for maximum speeds of 330 km/h. This type of rolling stock is used for the ICE Frankfurt, and provides interoperable technique. In order to realise this alternative, the current infrastructure will be upgraded between Amsterdam and Hannover – "Ausbaustrecke" (total length: 375 km). Between Hannover and Berlin, ICE infrastructure exists already. Overall, the infrastructure alternative realises new infrastructure at current sections, wherefore it is considered as a combination of both variables (improved and new infrastructure). The resulting measurements are summarised in Table 4-1.

Table 4-1: Infrastructure alternative – dedicated high-speed line.

Infrastructure alternative:	Dedicated high-speed line.		
New [1]	Improve [2]	Remain unchanged [3]	*Time "gain" [4]*
- Double tracks	- 6 stations NL	- Route	- ***~2.6 h***

- 169 km NL - 206 km DE - ICE3 (max speed): 330 km/h	- 6 stations DE	- Intermediate stops	*Gain, compared to current travel time.*

Table 4-1 shows the adjustments required to realise the infrastructure alternative. Column 1 indicates the number and track length, which needs to be built (new). Furthermore, the ICE3 needs to be purchased. Column 2 shows, the stations that need to be adjusted (improve) in order to facilitate the ICE service. From the 16 intermediate stops, the stations Osnabruck, Hannover, Wolfsburg and Spandau are already part of the ICE network (see Appendix K). As ICE services do not yet operate the remaining stations, infrastructural adjustments are assumed to be required. The route as well as the number of intermediate stops remain unchanged (column 3).

With this setting, a new travel time calculation is performed (Appendix G). It is highlighted that the calculation is based on pessimistic assumptions. For instance, the maximum speed is set to 300 km/h. The acceleration and deceleration factor are considered to be equal with 0.5 m/s^2. The minimum running time supplement is 5% for both countries (Siefer & Fangrat, 2012). Rounding the supplement to full minutes and using a conservative approach reveals in a running time supplement of 14%. The entire calculation as well as the comparison to an optimistic calculation is described extensively in Appendix G.

As the pessimistic (conservative) travel time calculation shows to be more applicable in reality, this travel time is chosen for all later calculations related to the infrastructure alternative. The travel time savings (column 4), are obtained by subtracting the new travel time (222 minutes) from the current travel time (379 minutes). Overall, the infrastructure alternative reveals in a travel time saving of approximately 2.6 hours (157 minutes). This reveals in an operational (average) speed of 170 km/h and thus fulfils the criteria of international networks as provided in chapter 2.

ROLLING STOCK ALTERNATIVE

The second alternative incorporates the two measures: higher speed and interoperable technique. The latter enables the IC Berlin to drive directly over the border, without the necessary locomotive change. In this way, the travel time can be reduced by 10 minutes. Additionally, the new intercity fleet provides higher maximum speeds. However, as on the infrastructure between Amsterdam and Bad Bentheim, no higher speeds than 130 km/h are allowed, the utilisation is only possible on the German network. As the increased maximum speed from 200 km/h to 230 km/h are currently discussed between the operators, this property is listed. However, the utilisation of the higher speed requires insight into the German timetabling, which is at this stage of the study not provided.

In order to make use of the 10 minutes stopping time reduction at the border, the timetable needs to be adjusted. A running time calculation from 2014 (based on the timetable 2014), revealed in a slack time of nine minutes throughout the Dutch timetable. In order to provide travel time savings on the entire line, the slack time within the German network is assumed to be comparable. This assumptions is derived from conversations with DB. The entire calculation of the travel time reduction is provided in Appendix H. It is highlighted that the travel times vary between the years by 10 minutes. Moreover, travel time calculation depend on the train paths of other trains. Therefore, NS and DB use software to obtain the exact travel times for national services. For international services however, such software support is limited. Thus, the determination of international train paths, requires the cooperation among operators. In the case of the IC Berlin, NS and DB negotiated about the possible travel time savings for an alternative as here presented. The travel time savings are derived from these meetings (see Appendix H).

Table 4-2, lists the main characteristics of the rolling stock alternative. Compared to the reference case, new rolling stock of 230 km/h needs to be purchased (column 1). With interoperable technique, the situation in Bad Bentheim as well as the timetable can be improved (column 2). The number of intermediate stops, as well as the route remain unchanged (column 3). Overall, 10 minutes stopping time in Bad Bentheim and 20 minutes throughout the entire timetable are gained with this alternative (column 4).

Table 4-2: Rolling stock alternative - Multi current locomotive with maximum speed of 230 km/h.

Rolling stock alternative:	Multi current locomotive.	Maximum speed 230 km/h.	
New [1]	Improve [2]	Remain unchanged [3]	Time "gain" [4]
IC rolling stock with maximum speed of 230 km/h.	No locomotive change in Bad Bentheim Timetable	Intermediate stops Route	Bad Bentheim 10 min Timetable slack 20 min

NETWORK ALTERNATIVE

The network alternative incorporates three variables, namely the adjustment of route, the reduction of intermediate stops and an increase in frequency. As explained in the infrastructure alternative, the directness of the IC Berlin is high. An alternative route will thus lead to higher travel times. As the demand elasticities show, travellers are the most sensitive for fare and travel time attributes. For this reason an increase in travel time, will lead to a decrease in passengers, which might be compensated by serving new OD-pairs. However, for the German national market, domestic demand is unknown. Therefore, alternative routes in the Netherlands are suggested. As the ICE Frankfurt operates Arnhem and Utrecht and competing effects among NL-DE services are not desired, the new route for the IC Berlin is aligned over Zwolle (column 1). An advantage effect is expected from the use of the Hanzelijn, which is part of the route over Zwolle and is built for speeds up to 200 km/h.

The second measure refers to the reduction of intermediate stops. Since Zwolle provides direct connections to the south and north of the Netherlands, this stop is considered as important transfer node in the Dutch network. In order to increase the accessibility for people outside the Randstad to international service, and in order to improve the travel time for international passengers, solely this station will be served. On the German side the major transfer nodes, Osnabruck and Hannover will be operated. In total the number of intermediate stops will be thus decreased from 14 to three stops only (column [1]). With the comfort of fast connections to the big nodes along the line, business passengers shall be attracted. This effect is supported by an increase in frequency from 0.5 per hour to ones per hour and direction (column [2]). A higher frequency is not interesting for international passengers as explained in chapter 3. The rolling stock is considered to be equal to the one in the reference case (column [3]).

The total gains are twofold. First, the travel time will be reduced by 35 minutes. Second, the waiting time will be decreased.

Table 4-3 summarises the characteristics of this alternative. In column [4], the "gains" are presented. Based on the model, which will be explained in section 4.3, the new travel time over Zwolle is calculated. As the Hanzelijn provides higher maximum speeds, the travel time over Zwolle is reduced by 13 minutes. This travel time incorporates all intermediate stops on this route. The model shows, that another 22 minutes can be gained, by the reduction of intermediate stops (11 stops x 2 minutes dwell time). The time losses due to acceleration and deceleration are incorporated in the average speed the model uses per link (see also sub section 4.3.3). Thus, the 35 minutes travel time reduction are obtained from the model, which will be explained in section 4.3. The alternative reveals in travel time gains of 35 minutes and a doubled frequency.

Table 4-3: Network alternative – Line over Zwolle, Osnabruck and Hannover with a doubled frequency.

Network alternative:	3 stops and	Double frequency.	
New [1]	Improve [2]	Remain unchanged [3]	Time "gain" [4]
Route over Zwolle. 3 intermediate stops.	Frequency.	Rolling stock characteristics.	Route: 13 min Stops: 2 x 11 = 22 min Double frequency

REVENUE ALTERNATIVE

The final alternative requires the least adjustments of the current service, and is expected to have high generation effects. The latter is related to the high amount of non-business passengers using the current service. As chapter 3 shows, this type of passenger is the most sensitive to fare changes. However, the fare change will be solely applied on international fares. As for domestic users the IC Berlin is provided as regular IC service, domestic passengers pay no supplement. However, a decrease in fare price for national users, will lead to a demand shift from domestic lines, to the IC Berlin. A sprinter service for instance will then loos demand, as passengers prefer to use the cheaper transport mode, with longer access/egress ways. The reaction of domestic passengers on price differences is not subject of this study and thus, excluded from the fare alternative.

The new price for a trip to Berlin will decrease from, in average 65 euros, to 50 euros. The fare reduction of almost 25% is reasoned by the comparison with the alternative modes. In order to make the train more attractive, the price is lowered by 15 euros. The ticket price is then 50 euros for a single trip and is thus cheaper than the car and airplane. The complete comparison is presented in Appendix L.

Table 4-4: Revenue alternative – Decrease in ticket price.

Revenue alternative:	Decrease in ticket price		
New [1]	Improve [2]	Remain unchanged [3]	Money "gain" [4]
	- Decrease international ticket price.	- National prices.	- 15 euros per trip and direction.

All four alternatives are summarised in the following table:

Table 4-5: Alternatives and their improvements.

		Improvements (Amsterdam-Berlin)		
Alternative	Measure in reality	Travel time	Fare	Frequency
		[hours]	[€]	[hours]
Reference	-	6.3	65	0.5
	IMPROVEMENT	*0%*		
Infrastructure	Dedicated high-speed line between Amsterdam and Hannover.	3.7		
	IMPROVEMENT	*42%*		
Rolling stock	Multi current locomotive with maximum speed of 230 km/h.	5.8		
	IMPROVEMENT	*8%*		
Network	IC Berlin over Zwolle (Hanzelijn).	5.7		1
	IMPROVEMENT	*10%*		*100%*
Revenue	Single ticket 50 €.		50	
	IMPROVEMENT		*23%*	

4.3 Quantification of Alternatives – Lijnvoeringsmodel - (B)

The Lijnvoeringsmodel (LVM) is an NS tool established in 2011 to provide an insight of costs and revenues of the network. In addition, each line (service) can be quantified separately. The model is based on the graduation of Niek Guis (Guis, Keizer, & Nes, 2012). His work aimed to create an optimal future train service for the Netherlands, if the current services are neglected and only demand and network characteristics are known. In order to achieve this goal, the author used the genetic algorithm, which runs through four steps per iteration, namely:

1. ***Determination of initial population.***
2. ***Determination of scores per network.***

3. **Choice for "reproduction".**
4. **Selection of the elite.**

The four steps are described in Appendix G. Based on the prototype Niek Guis established, the LVM is build up. It incorporates the steps of the genetic algorithm and refines various steps. In the following sub section the highlighted model steps 1 and 2 used for the Dutch network are explained in more detail. Based on the input and constraints the user determines upon front, the model enables to either calculate certain alternatives only, or optimise the entire network. The model seeks to provide a solution on a strategic and tactical level. Aspects of the operational level, as for instance timetable planning are excluded from this model. The limitations of the model are explained in sub section 0. In order to use the model for international networks, modifications of the model are required (4.3.4). Finally the model is used to quantify the predefined alternatives (4.3.5).

4.3.1 Model steps

For further understanding the model steps between iteration step 1, the determination of an initial population and step 2, scores per network are described. The model runs several iterations until the stop criteria is fulfilled. An overview of model steps is given in Table 4-1:

Table 4-6: Model steps LVM.

Iteration X	
Model step	Method
(I) Network	
(a) Generation of lines	"Genetic algorithm"
(II) Travel options	
(a) Generation of options	"Breath-First-Search algorithm"
(b) Remove of (unnecessary) options	
(III) Demand	
(a) Trip generation	"Elasticity model"
(IV) Assignment	
(a) Evaluation of options	"Utility function (=disutility)"
(b) Distribution over network	
i. Weighting travel option	
ii. Distribution of passengers	"MNL"
(V) Scores	"Objective function"

In Appendix C, the English explanation of the model steps can be found. Steps which are actively modified for the international network, are explained in section 4.3.4 in more detail. For further information readers are referred to the Dutch paper "Optimalisatie van de lijnvoering op Railnetwerken" (Keizer, Fioole, & Wout, 2013), which was written for the CVS congress 2013.

4.3.2 Input data and sub objectives

With a general understanding of the model steps (previous section), the model is applicable for the national setting. However, in order to extend the model for international purposes, new supply need to be inserted as network, vehicle speed, etc. (see also chapter 2 and chapter 3).

The input is split in two classes, namely network variables and parameters. The first incorporates fixed input data as for instance the number of stations, their GPS location, demand on OD pairs, etc. This network data is used to calculate a reference case. For the optimisation, different parameters need to be set. The difference is illustrated using an example of dwell times.

In the input data every station is assigned to a certain size. Amsterdam central station has for instance higher dwell times, than a station as Rheine in Germany, due to the amount of access and egress passengers. Instead of determining every dwell time separately, it is chosen to use five categories, namely kathedraal, mega, plus, basis, halte. For each category a value in minutes is set. The value incorporates dwell time as well as acceleration and deceleration information. Thus, in order to calculate the travel time, the LVM uses average speed, the station category and the distance between two ODs. Certainly, this is a strong simplification. However, for the Dutch national setting, with in total 400 stations, this approach proved to be close to reality. Realised travel times and outcomes of the model were validated.

The entire list of input data is provided in Appendix C.

With this input data, the network is modelled. With the parameters, different alternatives can be either tested or an optimisation conducted. As mentioned earlier (section OF), the network optimisation comprises the objective to maximise profit. However, this is the final outcome. In order to obtain this objective, different sub objectives are determined as for instance the decrease in the number of locomotives, personnel costs. The entire list is presented in Appendix C.

4.3.3 Limitations

Since the first prototype of the LVM in 2011, the model is improved constantly. The insights gained from the first pilot project were used for the future development of the current service as provided by NS. However, the model mainly provides a calculation tool for the fast, first financial estimation of alternative lines, as it does not incorporate timetable information. New generated lines are then tested with more sophisticated models as VISUM (if timetable path known) or Donna (if timetable path needs to be determined). As the model provides first insights and neglects timetable constraints, simplifications in the model construction are made. These simplification reveal in model limitations. Furthermore, the LVM is established for the Dutch network. As this differs from other networks, the national setting reveals in additional limitations.

Model characteristic:

- Capacity –
  - There are no track or capacity constraints, which prohibit the generation (by the algorithm) of travel options. However, the model does recognise if many alternatives are passing a certain link. These links, which face in reality capacity limitations, are visualised in the model. The same holds for stations capacity.
  - There are no personnel limitations. However, additional personnel is incorporated in the operational costs.
  - In reality, Dutch IC locomotives are restricted to the maximum amount of 12 wagons per train. This limitations is not incorporated in the model.
- Timetable – the model has no timetable information. Based on the predefined frequency, the departures are distributed equally over the cycle time of 60 min. Thus, a line with frequency 4, will depart at .00, .15, .30 and .45.

- Genetic algorithm – searches within the set of opportunities for an optimum solution. However, due to the mutation and combination process, the outcomes are not deterministic. This means that the solution of a following run can be different compared to the previous. For this reason, multiple runs are conducted and an average value is used.
- Unimodal – the model is unimodal. If train service changes, passengers might opt for competing transport modes and vice versa. However, the model incorporates train demand only.
- Trip generation – the generated demand, when improving train services, is covered by a generalised elasticity. The elasticity value does not distinguish between different service attributes or trip purposes. An improvement in travel time of 10 % will have the same effect as an improvement in fares of 10 % and is perceived similar by all passenger types (business, commute, leisure passengers).

National model specifications:

- Speed – the model uses an average speed, which is assigned to a network link. Different speeds per vehicle type cannot be implemented.
- Average speed – this value incorporates buffer times, which are in practice incorporated in the timetable to avoid the delay propagation over the network. In addition, the lower speed accounts for acceleration and deceleration time losses.
- Dwell times – are split in five different classes. The exact value per dwell time class can be adjusted. However, exceptional high or low dwell times (e.g. due to locomotive change in Bad Bentheim), need the introduction of a new dwell time class.
- Travel time – the travel time calculation is based on the average speed, the distance between two sequential stops and the dwell time per stop. In consequence, services that differ in speed as ICE and IC, cannot be tested in the national setting.

$$travel\ time = average\ speed\ on\ link * link\ length + dwell\ time$$

- Transfer penalty – the transfer penalty is based on the Dutch network and trip characteristics, as for instance home-work trips.
- Frequency – the national setting provides solely integer frequencies. Due to programming reasons, no rational numbers are supported. A frequency of ones in two hours (=0.5) cannot be modelled.
- Price- The national setting does not account for pricing strategies. In the Netherlands, the ticket price accounts for the shortest distance and is based on a standard tariff per kilometre. There is no differentiation among different services, as for instance in Germany. There the ICE is more expensive than the use of an IC.

4.3.4 Modifications – form national to international

MODEL STEPS

In this section the different model steps are presented, which need to be modified from the national setting to the international one.

Step (IIIa) Demand – Elasticity model - Unimodal

The initial demand from the input data (see Table 4-2) is based on the network and the initial service lines and indicated with D_0. For every iteration i_n the demand is indicated with D_n. Within each iteration the steps (I) to (V) are repeated. During the first two steps (I) and (II) the network and travel options are generated, which influence the demand. If the travel option is improved compared to D_0, the demand increase, otherwise it decrease. The new demand D_0 is calculated using an elasticity model:

$$D_n = D_0 * \left(\frac{GJT_n}{GJT_0}\right)^{E_{GJT}}$$

(Eq.) 4-1

Where,

$$GJT = waiting\ time\ (t_f) + invehicle\ time\ (t_{in}) + total\ transfer\ time\ (\sum t_o) + number\ of\ transfers\ (o) * transfer\ penalty\ (pen_o)$$

With:

GJT_n = Generalized journey time during iteration n; with n ∈ {*N*}

E_{GJT} = Elasticity for the GJT

As the GJT is composed by a number of different variables, (Eq.) 4.3-1 can be rewritten as:

$$D_n = D_0 * \left(\frac{(t_f + t_{in} + t_o + o * pen_o)_n}{(t_f + t_{in} + t_o + o * pen_o)_0}\right)^{E_{GJT}}$$

(Eq.) 4-2

The waiting time t_f is related to the frequency. The more frequent a train service is offered, the less time passengers need to wait in case they miss a train. For example the IC service from Delft to Amsterdam has a frequency of 4 trains/hour or every 15 minutes. Assuming an even distribution of passengers arriving at Delft station, one can derive an average waiting time of 15/2 or 7.5 minutes. For every other frequency the average waiting time is respectively 60/2/frequency(x) or 30/x.

From literature, perceived waiting times are derived, which are often higher, than the realized ones. One minute of waiting time for instance is experienced as two minutes. This doubling of perceived waiting time is noticeable for short waiting times below 10 minutes (t_f<10). Frequencies of 3/hour and lower (t_f≥10), show a decreasing trend. For the IC Berlin with a frequency of 0.5/hour, the perceived waiting time is determined with 63 minutes based on waiting time tables provided in the UK study (PDFH B, 2009).

In the national model, the different service attributes are aggregated to one generalized value (GJT). Changes in demand are calculated using the GJT-elasticity. As frequency and travel times for the international market differ from the national market, the international model seeks to distinguish between the different service attributes. In order to quantify the effects of a percentage change in a service attribute, the elasticities from chapter 3 are used.

Moreover, the national model does not encounter for fare changes. The price on the national market is always determined by the price per kilometre and the shortest route in the network. For this reason, the fare is not incorporated. As the international market competes with other modes, the price is a differentiating variable. Thus, for the international market the elasticity model is modified twofold. First, the train service attributes are disaggregated. Second, the fare attribute is added. The latter requires an extension of the GJT as used in the national model, namely:

$$GJT = t_f + t_{in} + \sum t_o + \beta(o * pen_{nat}) + \gamma(o * pen_{int}) + \gamma(p_{int} * d_{int})/VOT$$

(Eq.) 4-3

Where,

'pen_{nat} = national penalty of 10 minutes

'pen_{int} = international penalty of 20 minutes (source: (PDFH B, 2009) for trips > 50 km).

'p_{int} = fare per kilometre for the international market

'd_{int} = distance from any German destination until the Dutch border station.

VOT = value of time with 7.50 Euro/hour (12.5 cent/min)

'β = dummy variable for national use only

'γ = dummy variable for international use

The introduced dummy variable γ ensures the use of fares for international lines and is therefore defined as follows:

γ = 1 if, excel sheet "stations" → column "country" → DE

γ = 0 otherwise

β ≠ γ

Finally, the *international elasticity model* is presented.

$$D_n = D_0 * \left(\frac{(t_f)_n}{(t_f)_0}\right)^{E_f} * \left(\frac{(t_{in} + t_o + o * pen_{int})_n}{(t_{in} + t_o + o * pen_{int})_0}\right)^{E_t} * \left(\frac{(p_{int})_n}{(p_{int})_0}\right)^{E_p}$$

(Eq.) 4-4

Where,

$$\frac{(t_f)_n}{(t_f)_0}, \frac{(t_{in} + t_o + o * pen_{int})_n}{(t_{in} + t_o + o * pen_{int})_0}, \frac{(p_{int})_n}{(p_{int})_0} = \left(\frac{s_n}{s_0}\right) = the\ procentual\ change\ in\ train\ service\ attribute\ s$$

E_f = frequency elasticity

E_t = travel time elasticity

E_p = fare elasticity

Using the different elasticity values from chapter 3, the different demand effects are modelled. The transfer attribute is incorporated to the travel time. As many elasticities found in literature consider travel time elasticity for the entire travel time, including transfers, no distinction between transfer and travel time effects are undertaken. Certainly, transfers will hinder some passengers to take a travel option. Especially when considering transfer reliability, certain passengers will avoid this option. However, others will prefer the transfer option as it saves travel time. For these reasons, the transfer attribute is set equal to the travel time attribute.

Overall it is highlighted that elasticities are only valid ceteris paribus[9]. In conclusion, the modification from the national to the international model holds only, if one service attribute shall be tested. One example is the situation, where travel time decreases by 10 percent, due to less intermediate stops.

$$D_n = D_0 * 1 * \left(\frac{t_n}{t_0}\right)^{E_t} * 1 * 1 = D_0 * \left(\frac{t_n}{t_0}\right)^{E_t}$$

(Eq.) 4-5

[9] One attribute changes, whereas all other attributes remain unchanged.

Furthermore, the national model incorporates train demand only. With an insight into the demand of other modalities, competing effects are illustrated. (Here could be more).

Step (IIIb) Demand – Elasticity model – Multimodal

For the competing modes airplane and car, the trip generation is based purely on the changes of train service attributes. Thus, the elasticity model gives no indication about demand changes when the service attributes of plane or car change. Modelling this type of demand changes would be possible when direct demand elasticities for the competing modes are known. As this thesis focuses on the train service between the Netherlands and Germany, effects of modified train service attributes are investigated solely. Due to the elasticity characteristic ceteris paribus (see also "Limitations") the attributes of car and plane remain constant.

The multimodal model is presented in addition to the unimodal model. Whereas in step (IIIa) the train demand is generated by the change in a train service attribute, the multimodal model shows the demand changes of competing modes, due to the improvement in train services. In this way the train service is linked to the demand of other modes. In (Eq.) 4.3-6 the modal shift from train to a competing mode k is displayed. By worsening the service, people switch to another modality. Yet, if the train service improves, people refuse the competing modality:

$$D_{k,n} = D_{k,0} + D_{r,0} * (\left(\frac{S_n}{S_0}\right)^{E_{kr,s}} - 1)$$

(Eq.) 4-6

With:

$D_{k,0}$ = Initial demand competing mode

$D_{k,n}$ = Demand competing mode after n iterations.

$E_{kr,s}$ = Cross-elasticity for the mode k, when changing the service attribute s of mode r (rail).

The initial demand for all modes is inserted as input data, from which the total demand results. Improving service attributes of the train service leads to new trips on one hand and modal shifts on the other hand. The total demand results as sum of the demand of all modelled modes.

$$D_{tot} = \sum D_k + D_r$$

(Eq.) 4-7

NATIONAL SPECIFICATIONS

The presented adjustments are applied to the model steps. In order to use the model for the German market, the supply side needs to be adjusted. With the supply side mainly the network and rolling stock characteristics are meant.

The German network is inserted by nodes, their GPS locations and their connecting links. As source the two recent DB service maps are used (see Appendix K). The maps provide an insight, which lines are currently operated, their frequency and which stations are served. Due to the reason that the entire demand for the German network is not available, only relevant stations are represented in the LVM. In particular stations, which are primary and secondary stations (explained in section 3.1). Furthermore, additional lines and their stations are illustrated in the LVM to frame the German network. It is highlight that at this stage of the model, all lines except the international lines, have no additional value. However, in future scenarios where more national German demand is known, the lines might provide alternative travel options.

In addition to the network, the German rolling stock needs to be implemented. Based on the Dutch model specifications, travel times depend on the number of intermediate stops and not the speed travelled (section 4.3.3). Yet, the German service is extended by the high-speed service ICE. The German IC service provides equal average travel times as the Dutch intercity. Therefore, this type of rolling stock needs no further adjustments. However, in order provide the speed difference between the IC and ICE service, an ICE travel time factor V_{IC} is introduced.

$$ICE_{travel\ time} = IC_{travel\ time} * V_{IC}$$

In the reference case the average speed for the ICE is 112 km/h. This leads to a travel time factor of V_{IC}= 1.1. With this adjustment the model is able to calculate different travel times, dependent on the IC speed.

Furthermore, the national model does not differentiate in the service type, when calculating the ticket price. The fare is thus calculated based on the shortest path distance. For the international model however, a difference between IC and ICE services needs to be made. Therefore a supplement per kilometre is introduced. As national passengers use the IC Berlin as regular intercity service, they pay no additional fee. However, for all international passengers, the ticket price can be adjusted independently. In addition to the revenue, the German vehicles provide different costs. Based on realised data, the cost per kilometre are determined and defined as another cost variable, in the model.

4.3.5 Model validation

Just after the model is validated, the outcomes are considered to be reliable, and thus useful to evaluate the predefined alternatives. As the model was initially established for national purposes, the model is validated for the national use earlier by NS. Therefore, this validation focuses specifically on the model behaviour for the international lines.

The model outcomes are validated in two ways:

1. **Comparison with output VISUM[10].**
2. **Analysis of passenger numbers on plausibility.**

In the first step, the passenger kilometres (pax km) calculated with the international LVM are compared with the calculations of VISUM (NS). VISUM is a train transport model used by NS, which assigns the passengers towards available train services. It is based on two main input files, namely an annual demand matrix and the respective timetable. For the first, NS collects realised data (e.g. OV-chipkaart data) and composes it to an annual demand, which distinguishes between week and weekend day. This demand matrix is the same as used for the LVM (see also section 3.1). Thus, the comparison is based on the demand of 2014. As both models, use the same input file, it is expected, that they provide the same outcome. Due to the reason that VISUM is validated, an equal result will lead to the conclusion that also the LVM provides reliable outcomes.

However, since VISUM is made for the national network (NL), it provides only the national passenger kilometres. In contrast, the LVM provides the entire amount of passenger kilometres on this line (national and international). A separation between national and international passenger kilometres is difficult. Thus, in order to make the outcomes comparable, the international trip kilometres need to be added to the provided passenger kilometres from VISUM. With the IC Berlin line matrix of 2014 (used in section 3.1), the average trip length and thus, international passenger kilometres are calculated (see Appendix F). The comparison of the model results is illustrated in Table 4-7. The ratio between the LVM and VISUM outcomes shows a compliance of 95 percent. In other words, the model underestimates the realised passenger kilometres by 5 percent.

Table 4-7: Comparison with output VISUM (2014).

	Model results (based on 2014 input)	Realised data (2014)	Model reliability
Passenger kilometre			
National		~ 222,447 pax km	

[10] NS assignment model.

International	939,387 pax km	763,920 pax km	0.95

Nevertheless, the comparison between both models provides solely the insight that the LVM calculates the passenger kilometres correctly. However, the comparison shows not whether the LVM uses the estimated elasticities correctly or not. Therefore, a second approach is undertaken: the analysis of plausibility (point 2). Due to time and relevance, solely OD-pairs of the IC Berlin are tested. The idea behind is simply to check, whether the programmed elasticities are properly used, if the model experience changes.

Since the change in passengers is calculated differently for national and international passengers, both "trip types" are distinguished. In Table 4-8 the comparison is presented. Appendix F presents the entire calculation. Based on a travel time decrease of approximately 10 percent, the passenger numbers are calculated. The table shows for international passengers a growth of around 6 percent. As the travel time elasticity is set with -0.6, the increase in passengers is in line with the expectations. Hence, the outcomes are plausible.

Table 4-8: Analysis of passenger numbers on plausibility.

	Travel time decrease	Model outcomes (average)	Manual recalculation	Plausible?
International (travel time-elasticity = -0.6)	10%	6.25%	6.5%	yes
National (GJT-elasticity= -0.8)	10%	4.05%	-	yes

The national passengers are calculated based on a GJT-elasticity of -0.8. As this is a summation of waiting, transfer and in-vehicle time of all available travel options, the national OD-pairs are analysed in more detail (see Appendix F). As the model calculates the GJT over all available travel options, the attraction of an improved travel option (as presented by the reduced travel time of 10%) decreases, the more alternatives passengers have. Furthermore, the travel time reduction displays only a part of the entire GJT. Therefore, the increase in passengers is lower than 8 percent. Overall, a set of six national OD-pairs was tested and approved to be plausible (see Appendix F).

Based on the first and second approach, the conclusion is drawn that the model outcomes related to passengers and passenger kilometres are correct. The model is hence validated. Due to the reason that the validation does consider a small number of tested values only, no statements about over or underestimation is made.

4.3.6 Model outcomes

With the modifications of the model steps, as well as the introduction of the German demand for 2024 and the supply side (Network, lines, frequency, etc.), the LVM is used to quantify the different alternatives determined in section 4.2.

Among others, the model provides financial outcomes for the entire network, as well as outcomes dedicated for the international lines. In order to understand the performance of each alternative, the IC Berlin line is considered solely. In a first step, the reference case is modelled. Afterwards, the alternatives are compared with that case.

Although the national setting of the LVM was validated for national runs, the international calculations are tested on their plausibility. For this reason, first all runs (reference case and alternatives) are presented in Table 4-7. Second, the table includes hypothesises about the expected outcomes in a qualitative way. In a third step, the passenger kilometres and number of passengers are compared with the reference case.

Table 4-9: Alternatives – Improvements and expectations.

					Improvements (Asd-Berlin)			TT factor	Hypothesis
Alternative	**Variable**	**Measure in reality**	**2014**	**2024**	**Travel time**	**Fare**	**Frequency**	**V ic**	
					[min]	[€]	[-]	[-]	
Reference	**-**	-	**X**	**X*growth f.**	**379**	**65**	**0.5**	-	-
		IMPROVEMENT			*0%*				
Infrastructure	· New infrastructure	Dedicated high-speed line between Amsterdam and Hannover.							
	· Improved infrastructure	Use of the DB fleet ICE3							
		Average speed	98 km/h	170 km/h					
		Travel time	379 min	222 min	157			**1.73**	**+++**
		IMPROVEMENT			*42%*				
Rolling stock	· Higher average speed	Multi current locomotive with maximum speed of 230 km/h.							
	· Multi current locomotive	Stopping time at Bad Bentheim.	12 min	2 min	10				
		Extra slack time in time table.	30 min	10 min	20			**1.08**	**+**
		IMPROVEMENT			*8%*				
Network	· Change route	IC Berlin over Hanselijn and Zwolle.							
	· Less stops	Only Zwolle, Osnabruck and Hannover served.	48 min	9 min	39				
	· Higher frequency	Departures per hour and direction.	0.5	1			Double	**1.11**	**++**
		Resulting waiting time	63	39					
		IMPROVEMENT			*10%*		*100%*		
Revenue	· Decrease in price.	Single ticket 50 €.	65 €	50 €		15		-	**+++**
		IMPROVEMENT				*23%*			

In the reference case, the IC Berlin operates as today with a travel time of 379 minutes, an average ticket price of 65 euros and a frequency of 0.5 per hour. However, over the years an annual growth in demand will be realised, which is modelled in the reference case. Based on this data, the alternatives are compared.

As Table 4-7 shows, the alternatives differ in their improvements. For the infrastructure alternative, the highest travel time reduction can be realised with 157 minutes or 42% of the total travel time compared to the reference case. In order to realise this alternative, high-speed rolling stock is required. As the travel time gains are only realised, if the average speed increases from 100 km/h to 170 km/h, the new rolling stock needs to be in average 1.7 times faster, than the current IC. This is modelled using the travel time factor V_{IC} with 1.73.

The rolling stock alternative realises a travel time reduction of 8%, which accounts for a travel time factor of 1.08, and is the lowest among all alternatives. In contrast, the network alternative, which skips 11 stops, provides a travel time decrease of almost 11%. Furthermore, the network alternative provides a double in frequency, which will attract additional passengers. The last alternative reveals in a money saving of 15 euros for the trip Amsterdam-Berlin.

As the regarded international passengers are mostly travelling for leisure purposes, the elasticities for leisure passengers are used. As presented in section 3.5., this type of traveller group is the most sensitive towards fare. The demand reaction on this service attribute is considered with an elasticity of -0.8. For the travel time, an elasticity of -0.6 and for frequency -0.2 are used. However, these elasticities count for international passengers only. For the national passengers, a generalised journey time elasticity of -0.8 is remained. In line with these sensitivities of passengers, the qualitative hypothesises are stated.

For the infrastructure alternative, the highest travel time gains are provided. With the revenue alternative, the highest money savings are provided. For these two alternatives thus, the highest growth in passenger numbers as well as passenger kilometre is. Therefore, the hypothesis is indicated with three plusses (+++). For the rolling stock alternative, the lowest gains are calculated, hence the increase in passengers and passenger kilometres is expected to be the lowest.

The outcomes of the model are presented in Figure 4-3. As all alternatives are compared to the reference case, the improvement or worsening are presented. The 0% x-axle represents the performance of the reference case. As expected, the infrastructure alternatives, provides the highest improvement. However, one can see that the number passengers increases more than the passenger kilometres. This is reasoned by the fact that the travel time improvement is distributed linear over the entire line. Domestic passengers used this line as an alternative travel option for short distance trips. However, with the strong improvement of 42% in travel time, national passengers prefer the international line above the national travel options. In conclusion, passengers between Amsterdam and Hilversum for instance reject the Sprinter and opt for the faster IC Berlin. Also for international passengers, the infrastructure alternative provides the highest attraction.

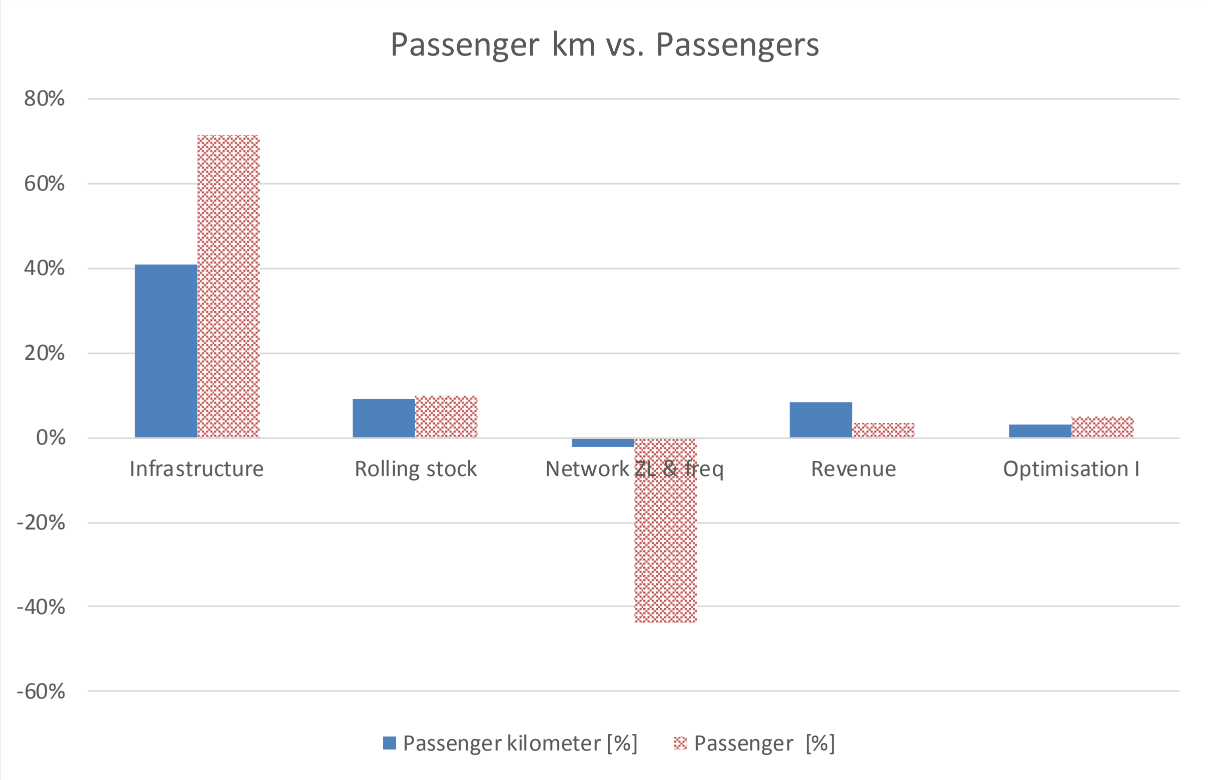


Figure 4-3: Passenger kilometres vs. Passengers.

For the rolling stock alternative, the increase in passengers and passenger kilometres is comparable. However, the number of passengers increases slightly more than the passenger kilometres. Again, the travel time gains are evenly distributed over the entire line. National short distance travellers are more attracted as international, due to the higher elasticity compared to international travellers. Furthermore, the national passengers account for approximately 75% of all passengers. In contrast, the most passenger kilometres are provided by international passengers.

Thus, for a linear decrease in travel time, where both, national and international passenger benefit from, the number of passengers is higher, than the passenger kilometre made. This is mainly reasoned by the composition of national and international passenger in the train.

The third alternative runs over Zwolle, passes in Germany the stations Osnabruck and Hannover and is operated ones per hour. The new route and skipped stops, lead to an improved travel time, which attracts passengers on the served OD pairs. However, on the intermediate stations, demand is lost. Thus, in comparison with the reference case, this alternative loses passenger and performs worse. Again the figure reveals in the composition of national and international passengers. Whereas the passenger kilometres decrease by 2% only, the reduction of passengers is significantly higher. As from the seven national stations, only two are served, the passenger number is strongly reduced.

Alternative four, the revenue alternative, reveals in a fare reduction for international trips. In the hypothesis, this alternative was assumed to perform as high as the infrastructure alternative. As the fare reduction does not hold for national passengers, the increase in passengers as well as passenger kilometres is solely related to international passengers. As they determine a relatively small amount of all users, the low increase is justified.

As a last, the optimisation over the Dutch and German network is performed. The initial population is set with 50. This implies that 50 different networks are determined, where the available lines are composed differently. The optimisation is based on route, stop and frequency adjustments. Furthermore, 1000 iterations are performed, before the genetic algorithm stops. In total, five optimisations are performed. However, as the optimisations differ only slightly, they are summarised to an average value. From the optimisation the following aspect are concluded:

- The currently operated Dutch network does not perform optimal, as an increase in revenue is suggested by an decrease used currently used rolling stock.
- For the IC Berlin no increase in wagons is suggested. However, more passenger travel with the international service.
- As the number of passengers increase more than the travelled passenger kilometres, the additional passengers are domestic passengers.
- The increase in domestic passengers is mainly caused by the fact that the IC Berlin is modelled with a frequency of one. Hence, the service provided is not in line with reality.

Overall, the hypotheses stated upon front are not fulfilled. This shows, that a simple assumption based on the amount of travel time or fare decrease, does not account for the demand behaviour. As both, the national and international market are affected by service adjustments, but behave in different ways, the alternatives need to be modelled more sophisticated.

The model outcomes show in terms of national and international demand, the biggest gains, for the infrastructure and rolling stock adjustment. As in both alternatives the served stations do not change (compared to reference), no passengers are lost. In addition, the reduction in travel time over all stations provides an increase in passenger demand. As the most passengers of the IC Berlin are domestic users, the number of passengers increase more than the kilometre travelled. The fare alternative has the lowest positive impact. The network alternative loses by its alternative route more passengers, than it gains from the faster service.

As an final outcome of modelling alternatives the impact on the competing modes is presented. Due to the reason that there are solely the mode shares for the OD-pair Amsterdam-Berlin known, the modal shift for this relation is presented. In Figure 4-4, the impact per alternative are presented. Furthermore, the impact of the optimisation are presented. In this comparison the infrastructure alternative provides the highest attraction on passengers who switch from car and airplane to train. This is a plausible outcome, as the alternative provides the highest travel time gain, the most diverting passengers are expected. Thus, people who tend to use the car or air mode, are now willing to travel by train. During the optimisation no improvement on this relation is realised. This leads to the outcome that zero passengers shift from a competing mode towards train, in the optimisation scenario.

In section 3.4.6, the cross-elasticities for non-business passengers are calculated with 0.1 for frequency, 0.2 for travel time and 0.3 for fare changes regarding train services. This implies that the highest impact on modal shift will be realised by changing train fares. However, equally as in the direct demand modelling, this effect cannot be shown, as the revenue alternative improves the situation for the international passengers only. In addition, in every alternative more passengers are diverting from car than from air mode. This is simply explained by the fact, that only one OD-pair is considered for which the mode shares are used to calculate the cross-elasticities.

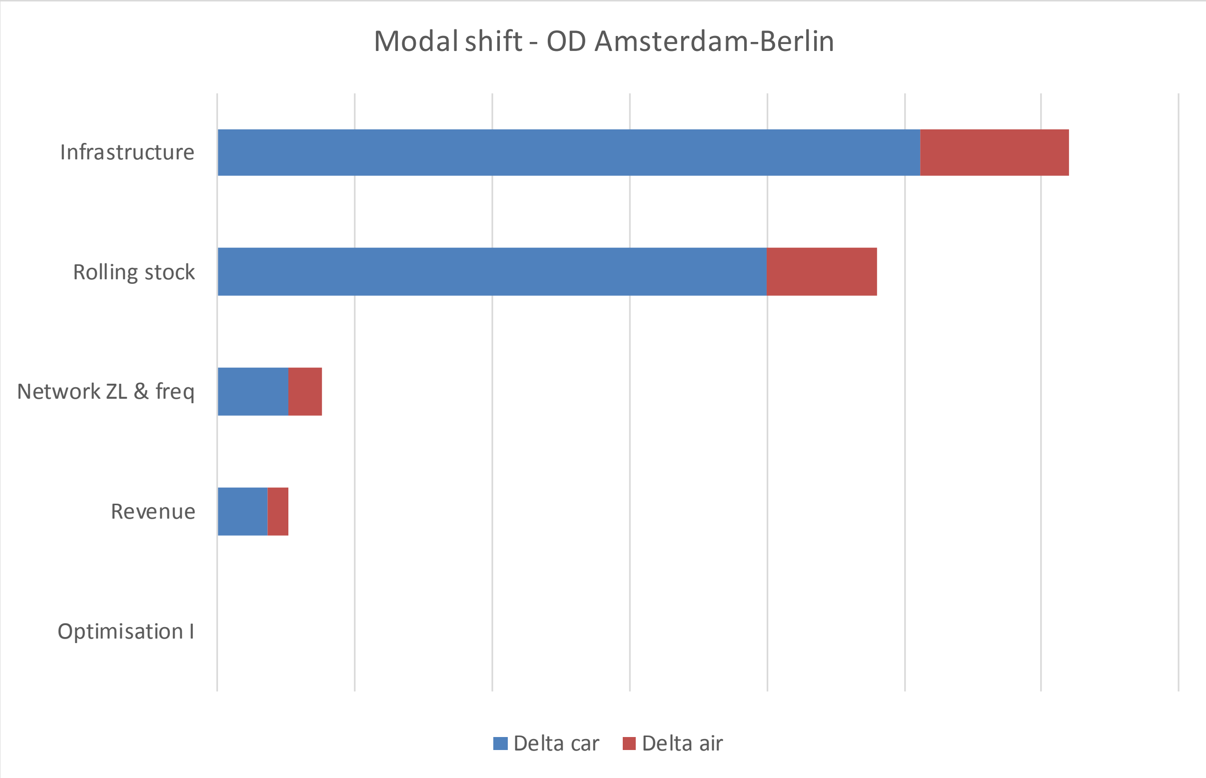


Figure 4-4: Modal shift Amsterdam-Berlin.

4.4 Conclusions – Service alternatives

In order to provide an appropriate service for the future IC Berlin, the following question is raised:

(3) How can alternatives for future services be determined?

For the future service, various variables related to costs or benefits might be adjusted. These are for instance network characteristics, time tabling, alternative rolling stock with higher maximum speeds, etc. In order to structure the different possibilities in an illustrative and logical way, the relevance tree is used (Ross (2001), Pfohl (1977)). The tree starts with the commercial objective to maximise profit. However, the objective function for public transport suggests the maximisation of social welfare, which incorporates both, the maximisation of producer and consumer surplus. Therefore, the relevance tree focusses on the revenue maximisation side. The tree continues with different global aspects as service improvements, and ends with the final measurements. Related measures are clustered to alternatives. With the entire tree, the next question can be answered.

a. What are the alternatives for the IC Berlin?

As the research seeks to define conceptual alternatives (on a macroscopic level), detailed measurements as the improvement of stations, or the use of tilting technology, are not explicitly investigated. Thus, from the application of the relevance tree on the IC Berlin case, the following four alternatives are determined:

- Infrastructure alternative – New or improved infrastructure.
- Rolling stock alternative – Faster fleet with multi current system.
- Network alternative – Different route, with less intermediate stops and higher frequency.
- Revenue alternative – With an adjusted ticket price.

Every alternative provides an improvement compared to the reference case, in terms of travel time, fare and frequency. With these improvements, more passengers shall be attracted. For each alternative, the improvements are calculated separately. The outcomes are displayed for the trip Amsterdam-Berlin:

		Improvements (Amsterdam-Berlin)		
Alternative	Measure in reality	Travel time	Fare	Frequency
		[hours]	[€]	[hours]
Reference	-	6.3	65	0.5
Infrastructure	Dedicated high-speed line between Amsterdam and Hannover.	3.7		
	IMPROVEMENT	*42%*		
Rolling stock	Multi current locomotive with maximum speed of 230 km/h.	5.8		
	IMPROVEMENT	*8%*		
Network	IC Berlin over Zwolle (Hanzelijn).	5.7		1
	IMPROVEMENT	*10%*		*100%*
Revenue	Single ticket 50 €.		50	
	IMPROVEMENT		*23%*	

As the alternatives provide different improvements, it is not clear, how the alternatives perform. In order compare them another question is formulated:

b. How can these alternatives be tested?

The alternatives are tested using the Lijnvoeringsmodel. This tool provides the user with two functions. First, the presented alternatives can be tested. Second, the entire network can be analysed on its performance, by running an optimisation. The latter is based on the graduation work of Niek Guis (Guis et al., 2012), who used the genetic algorithm for this purpose. However, this software-supported model is initially made to test the Dutch train services. In order to apply the LVM also for international services, the model is extended within the here conducted study. With the international setting, model-users are enabled to test alternatives for the Dutch-German network. Thus, additional to the IC Berlin, the ICE Frankfurt and ICE Basel are modelled. In order for decision-makers to extend the model by further alternatives, the following main steps are required:

- Supply side
  - Extension of the network, by the provision of nodes and links of the additional country.
  - Introduction of the new rolling stock types, their costs and respective speeds. For example, the characteristics of the Thalys, in case the Dutch-Belgium services shall be tested.
  - Introduction of competing modes.
- Demand side
  - Implementation of international demand. Preferable for all competing modes.
  - In case of accessibility, the national demand of the additional country.
  - Introduction of an international demand elasticity model, and the used of pre-investigated elasticities. In the here conducted study, the elasticities are derived from literature and expert opinions.

With the international setting of the LVM, the tool can be used to test the alternatives. The outcome shall provide an answer to the next question:

c. Which service alternative provides the highest demand?

This question is answered in two ways. First, the alternatives are tested. Afterwards, the optimisation function of the international LVM is used. The outcomes are compared to the reference case (see Table 4-10).

Table 4-10: Quantified alternatives – conclusion.

Alternative	**Service improvement**	**Passenger numbers**	**Passenger kilometres**

Reference case	-	X	X
Infrastructure	Travel time: 42%	+ 70%	+ 40%
Rolling stock	Travel time: 8%	+ 10%	+ 10%
Network	Travel time: 10% Frequency: 100%	- 2%	- 44%
Revenue	Fare: 23%	+ 8%	+ 3%
Optimisation	-	+ 3%	+ 6%

The full picture shows, that the infrastructure alternative performs the best for both, national and international passengers.

This outcome is related to the high amount of travel time savings. With a travel time decrease of 42% compared to the reference, the new infrastructure attracts around 70% more passengers and reveals in 40% more trip kilometres. The comparison of increase in passengers and passenger kilometres shows that evenly distributed improvements over the entire line, affect more national than international demand. This is caused by the fact, that the majority of passengers uses the IC Berlin for domestic trips. Passenger kilometres however, result from international traffic, and are thus less.

Although, the network alternative provides the second highest gains (travel time) and additional frequency improvements, the alternative loses passengers. Modelling this alternative shows, that the additional passengers gained by the service improvement, do not compensate for the lost demand on the 13 intermediate (skipped) stops. Since the highest elasticity is assigned to fare changes, the revenue alternative is supposed to perform high, with a decreasing fare of 23%. However, this price reduction is only applied for international tickets. In conclusion, the revenue alternative generates less passengers than the rolling stock alternative (8% travel time improvement).

Finally, the optimisation is performed. This calculation optimises the entire network based on frequency, stop density and alternative routes. After ten model runs (1000 iterations per run), the optimisation reveals in the same service (frequency, stop, route) as provided by the reference case. Thus, given the Dutch national and the two line matrices, the international services cannot be improved. Due to the missing German demand, alternative routes are not profitable. Nevertheless, the model shows a low increase in passengers and passenger kilometres. This is mainly reasoned by the frequency limitation of the model. Due to the overestimated frequency, national passenger have more travel options. For the respective line matrix, the frequency overestimation is compensated with a similar increase of the line matrix. However, national passengers outside the reference matrix are not incorporated. Hence, a small increase in passengers is shown.

As elasticities are only applicable for small changes in service, the outcomes of the infrastructure alternative are questionable. However, according to the demand elasticity model it is logical that the highest travel time reduction will result in the highest demand generation.

PART C

5 Societal evaluation of international lines

As the alternatives result in adjustments across the border (international), and the number of stakeholders increased, compared to national projects, a societal evaluation is conducted. This method is closer described in the first section. The effects, which result from such projects, are listed in the second section. However, only four of the five effects are selected. The third section describes the five scenarios, which consist of the reference case, and the four previously defined alternatives. Afterwards, the necessary assumptions are listed, which are required to evaluate the described alternatives. Since the evaluation is based, among others, on the reliability of the earlier determined elasticities, a sensitivity analysis is conducted. In section eight, the costs and benefits are distributed over the respective stakeholders. The chapter ends with a reflection on the outcomes and the answer to the fourth and last sub research question.

5.1 Method

Given the relevance tree and the used LVM, the alternatives are tested based on the goal of increasing profit. As explained in chapter 4.2.1, the operators NS and DB, operate on a commercial basis. Hence, services are offered, if they are profitable or at least cost-covering (see also chapter 4.2.1).

However, the objective of international services seeks to maximise social welfare. This incorporates the summation of consumer and producer surplus. In case of the IC Berlin, the goal is translated to the maximisation of operator, passenger and third party benefits. In order to evaluate alternatives on these aspects, a social cost benefit analysis (SCBA) is conducted. This type of evaluation translates different effects into monetary values and is useful when evaluating cost intense infrastructure or transport projects. In a first step, the known costs and benefits are listed, which lead to the commercial evaluation of the project (CBA). By incorporating the second step, the social evaluation, external effects as for instance pollution are measured (SCBA). By subtracting the costs from the benefits the gross value per alternative is obtained. The alternative with the highest, positive gross value performs the best. Another approach divides benefits by costs. Alternatives with a benefit/cost ratio above one, indicate an increase in social welfare. The benefit/cost ratio is also used to evaluate the alternatives for the IC Berlin.

For the conduction of the societal evaluation, the report of the Dutch Ministry for Infrastructure and the Environment is reviewed (Bakker, Zwanevel, Berveling, Korteweg, & Visser, 2009). However, due to the cross-border characteristic of the alternative services, extensive monetary insights for both countries and operators are necessary. Especially the latter, which includes domestic revenues, requires insight into financial data from both operators. Due to competition advantages, operators treat financial information confidential and avoid to share these. For this reason a diminished version of the SCBA is chosen. Certain cost or benefit positions are aggregated. For instance the costs are summarised to one value per kilometre.

5.2 General effects

The alternatives modelled in chapter 4, are possible scenarios, which are compared to the nil scenario. The nil scenario, or reference case, represents the most likely situation in the future, if no measures are taken. In order to compare the alternatives with the reference case, costs and benefits need to be defined. The handbook used in this study (Bakker et al., 2009) describes five types of effects which can be measured in either costs or benefits.

1. **Direct effects for service and infrastructure providers – E.g. profit from operation, costs for infrastructure, investment risks, etc.**

Direct effects for the service or infrastructure provider are related to investments, if they are negative. These are for instance construction costs, but also operational costs as for instance for maintenance. In contrast to the expanses are the revenues listed, which reveal from for instance from ticket sale or infrastructure fees. For the here presented study the direct costs per train kilometre are determined. Besides the infrastructure fee, the price consist of personnel and energy costs as well as amortisation and interest rate. For the revenues the currently existing revenue per passenger kilometre is used. For the ICE this revenue is 20% higher.

2. **Direct effects for passengers – E.g. faster, cheaper or more comfortable transport, etc.**

The positive direct effects for passengers are related to an improved service. Examples are for instance a faster service, higher comfort, or cheaper tickets. Negative effects appear with the construction of new services. An example are higher chances of delays or the increased delay time. In order to evaluate the alternatives for the IC Berlin, the travel time savings and money savings are determined, passengers receive with the new service.

3. **Indirect effects – E.g. improvement of job or housing market, etc.**

Indirect effects result for instance from a direct effect as decreased travel times. With the idea that a faster connection between two agglomerations will lead to a stronger economic activity and hence a surplus in social welfare. However, the relations between a new train line and the improvement on the housing or job market are difficult to define unambiguously. Therefore, indirect effects are not considered in the evaluation of the IC Berlin alternatives.

4. **External effects – E.g. reduction of pollution, reduction of emission, etc.**

Positive external effects are achieved by the reduction of greenhouse gases of passengers shift from pollution intense modes to the train. Nevertheless, this amount is very low. However, building new infrastructure will decrease the value of landscape, flora and fauna will be hindered and inhabitants will suffer noises emissions. For the Dutch-German market cross-elasticities are calculated, for the OD-pair Amsterdam-Berlin. On this OD pair the CO_2 reduction is calculated. However, as the modal split for the entire network is not known, the here evaluated external effects are little.

5. **Distribution effects – E.g. costs and benefits that arise from international projects.**

Distribution effects provide an overview over the costs and benefits that appear spatially.

For this study, effect 1, 2, 4 and 5 are quantified. At this stage of the study, indirect effects (point 3) are difficult to measure, thus they are left out. The distribution effects are especially for international projects of high interest, as they show in which country (or for which operator) the costs and benefits appear. Overall, the entire project is evaluated.

5.3 Scenarios

The social cost benefit analysis is divided into the monetisation of effects and the performance of alternatives compared to the reference case. In order to understand the differences between the alternatives to the reference case, each scenario is explained briefly.

5.3.1 Reference case

In the reference case the scenario is described, which is the most likely to happen, if no adjustments are made. However, due to the age of the current locomotives new rolling stock is required from upon 2024. Four Dutch and five German locomotives compose the current fleet. In order to provide a smooth operation, a gross fleet factor of 30% is required in practice. This results in a fleet of 12 locomotives (9 locomotives x 30%).

For the reference case TRAXX locomotives are used from 2024. The prices incorporate the entire train set, composed by locomotive and wagons. In order to calculate the costs for the entire fleet the costs in Germany are considered to be equal as in the Netherlands.

5.3.2 Alternatives

The alternatives modelled differ in the type of measurement and are explained in the following. Furthermore, some assumptions are stated which are necessary to perform a SCBA.

Infrastructure alternative

The first investments start in 2017. The new infrastructure runs along the current route until Hannover. Between Hannover and Berlin, the existing infrastructure will be used. In total, the required high-speed infrastructure runs over 170 km in the Netherlands and 210 km in Germany. The investment cost per kilometre new infrastructure are derived from Dutch projects (Appendix L). The entire infrastructure consists of two railway tracks, one in each direction. The calculated prices account for one kilometre double track. In order to serve the same intermediate stops as in the reference case, the stations are adjusted, which are not part of the ICE network yet. These are in total six stations in the Netherlands and six in Germany.

For the infrastructure alternative, high-speed rolling stock is required. With a currently realised turnaround time of 1.75 minutes at the final stations, and a travel time of 3.7 minutes, a gross fleet of eight train sets is required.

Rolling stock alternative

The costs per train set[11] follow from internal communications between both operators. The investment cost are distributed evenly over the coming years until the operation starts (2024). The price for an interoperable EMU is considered to be 25% higher, then the rolling stock used in the reference case. However, due to the interoperability, less train sets are required. Based on the calculated travel time of 5.8 hours, a gross fleet of 11 train sets is calculated.

Network alternative

For the network alternative, the rolling stock from the reference case is used. Since the frequency doubles in this alternative, additional train sets are required. Although the travel time decreases compared to the reference, the high frequency requires a gross fleet of 20 train sets.

Revenue alternative

Since for this alternative no adjustments are required, the revenue alternative requires the same rolling stock as presented in the reference case.

5.4 Assumptions

In the following sections the calculated alternatives are evaluated in a monetary way and compared to the nil alternative. As the extensive insight in all cost and benefit positions for both countries is missing, some assumptions are made:

- The socio-economic situation, as for instance income, is in both countries comparable. Hence, cost or benefits that are known for one country, are assumed to be similar for the other country.
- The discount rate is chosen to be 5.5%. As future investments face economic uncertainties, a risk supplement of 3.0% is applied. The remaining 2.5% cover the interest rate suggested by the Dutch government (Rienstra & Groot, 2012).
- The value of time (VOT) is considered with 9.25 €/h. This follows from the recent publication of the Kennisinstituut voor Mobiliteitsbeleid and is an average for different passenger groups, including business and non-business. For leisure passengers the VOT is lower with 7.0 €/h. Although the majority of international passengers travels for leisure, the national passengers realise travel home-work trips. For this reason, the average of 9.25 €/h is considered representative (Warffemius, 2013).
- All prices are evaluated based on the price level of 2015.
- The scope of this project is 30 years from the moment new rolling stock is introduced (2024). It is highlighted that in reference projects (see Appendix L column Q) longer scopes are considered.

[11] Train set determines the composition of locomotive and a dedicated number of wagons.

- All investment costs are realised between 2017 and 2023 (7 years).
- All benefits are counted from 2023 until the end of the project scope.
- There is no residual value after 2054 (30 years).
- The reference case (nil scenario) requires new locomotives in 2024 for both countries.
- Costs for maintenance and operation of new infrastructure are in the reference cases calculated with 1% of the investment costs.
- One kilogram CO_2 is calculated with 0.78 euro.
- The share of operational costs is divided over the operators according to the share of infrastructure in the respective country. In this study it is assumed with 1/3 NS and 2/3 DB.
- Effects that are difficult to measure in monetary ways are indicated with a PM-item.

5.5 Effects monetised

With the assumptions made in the previous section, the direct and external effects are calculated. This section provides the equations used to monetise the effects. As the indirect effects are difficult to express in monetary ways, they are excluded from this calculations. The distribution effects result from the distribution of costs and benefits among operators and will be presented in section 5.8.

Direct effects – Operators

In a first phase, the investment costs for the operators are calculated. Each alternative, also the reference case, require investment in new rolling stock. Furthermore, for the infrastructure alternative, new infrastructure needs to be constructed. Although the infrastructure manager instead of the operator pays for the latter, the equation is similar and therefore here presented. Equation (Eq.) 5-1 shows the calculation of the investment costs. The costs per unit (c_x), in this case either per train set or per kilometre new infrastructure are multiplied with the sum of required units (x).

$$Investment\ costs = c_x * \sum x$$

(Eq.) 5-1

The second cost position for operators, the operational costs, are presented in equation (Eq.) 5-2. The costs per unit, in this case per train kilometre, are multiplied with the daily (d) train kilometres ($n_{r,km}$).

$$Operational\ costs = c_{r,km} * \sum_d n_{r,km}$$

(Eq.) 5-2

Finally, the operator benefits namely, the revenues from ticket sales are presented. In equation (Eq.) 5-3, one can see that the price per kilometre (p_{km}) is multiplied with the daily (d) number of passenger kilometres.

$$Revenues = p_{km} * \sum_d n_{pax,km}$$

(Eq.) 5-3

Direct effects – passengers

For the passenger effects, the resulting benefits are calculated. These are derived either from money saving, or from travel time savings, which are translated into monetary values. In order to determine the value for all new passengers, the rule of half is applied. The money savings are obtained with the following equation (Eq.) 5-4. First, the fare reduction per kilometres is calculated (p_{ref}-p_{alt}). The reduction is then multiplied with the number of passengers from the reference case ($n_{pax,ref}$) and their average trip length of 360 km. For the additional passengers (rule of half), the same is done but then multiplied with a factor of 0.5 (see also (Eq.) 5-6).

$$Money\ savings = (p_{km,ref} - p_{km,alt}) * n_{pax,ref} * 360 + rule\ of\ half$$

(Eq.) 5-4

The travel time savings are obtained as the delta of the average reference travel time (t_{ref}) and the average alternative travel time (t_{alt}). Since the passengers have different trip lengths, their travel times vary. However, with the knowledge on daily passenger kilometres (pax km), as well as the average speed per alternative (v) and the carried passenger numbers (n_{pax}), the average travel time is obtained:

$$t_{ref} = \frac{pax\ km}{n_{pax}} / v$$

The calculated average travel time are presented in Table 5-1.

Table 5-1: Average travel time and travel time saving.

Travel times	**Reference (t_{ref})**	**Infrastructure (t_{alt})**	**Rolling stock (t_{alt})**	**Network (t_{alt})**	**Revenue (t_{alt})**
Operational speed km/h	100	170	105	110	-
Average travel time	1.9	1.2	1.7	1.6	-
Time saving "gain"		0.7	0.1*	0.2*	-
* Due to rounding					

The same is done for the travel time resulting from the alternative. Based on the delta of both average times, the travel time savings are calculated. As presented in equation (Eq.) 5-5, the average travel time saving is multiplied with the passenger number of the reference case and the value of time (VOT) to monetise this value. For all addition passengers the rule of half is applied as presented in (Eq.) 5-6.

$$Time\ savings = (t_{ref} - t_{alt}) * n_{pax,ref} * VOT + rule\ of\ half$$

(Eq.) 5-5

$$rule\ of\ half = \frac{1}{2} * ((t_{ref} - t_{alt}) * n_{pax,new} * VOT)$$

(Eq.) 5-6

Finally, the external effects, or more precisely, the CO_2 reduction is calculated. Since the multimodal model is only applied to the OD-pair Amsterdam-Berlin, the reduction is straightforward. In a first step, the CO_2 production of a competing mode (car or airplane) per kilometre ($CO_{2,k}$) are multiplied with the total distance (km*trips) and the costs per kilogram CO_2. This results in the emission costs for a competing mode ($c_{em,k}$). The same is provided for the train ($c_{em,r}$). The difference in costs are the benefits, which result from the reduced number of cars or airplanes on this OD-pair.

$$CO_2\ savings = (CO_{2,k} * d * c_x) - (CO_{2,r} * d * c_x) = c_{em,k} - c_{em,r}$$

(Eq.) 5-7

5.6 Evaluation outcomes

After the effects are calculated per alternative, each scenario is compared to the nil scenario. Thus, the evolving costs and benefits of the reference case are subtracted from the appearing costs and benefits of each alternative. The societal evaluation of all alternatives shows that the rolling stock alternative performs profitable with a cost/benefit ratio of 3.5. However, since the revenue alternative requires no investment costs on one hand, but reveals in high money saving for passengers on the other hand, this alternative provides the highest benefit/cost ratio. All outcomes are presented in Table 5-2.

Table 5-2: Societal evaluation of alternatives – outcomes.

	IC Berlin		30 years	Discount	factor:	5.5 %
			ALTERNATIVES			

	1	2	4	5	6	7
	Item	**Unit**	**Infrastructure**	**Rolling stock**	**Network**	**Revenue**
1	Cost					
2	Investment costs (Infrastructure)		-19,300	0	0	-
5	Investment costs (new rolling stock)		-110	-20	-80	-
8	Operational costs		-240	0	-150	-
11	**Total costs**	**[M€]**	**-19,650**	**-20**	**-230**	-
13	Benefits					
14	*Operators*					
15	Income ticket sale		330.0	40.0	-10.0	-20.0
21	*Passengers*					
22	Money savings		-	-	-	40
25	Travel time savings		190	30	20	-
29	*External effects (Asd-Ber)*					
30	CO2					
31	Car		1.8	1.3	0.2	0.1
32	Air		5.1	0.5	0.2	0.1
33	*PM items*					
34	Indirect effects	PM1	(+)		(-)	
35	Not served demand	PM2			(-)	
37	Service reliability	PM3	(+)		(-)	
38	Traffic safety	PM4	(+)	(+)	(+)	(+)
39	Landscape and nuisance	PM5	(-)		(-)	
40	**Total benefits**	**[M€]**	**520**	**70**	**20**	**20**
41	**Delta benefits**					
43	**Net Present Value**	**[M€]**	**-19,130**	**50**	**-210**	**20**
44	**Benefit/cost ratio**		**0.0**	**3.5**	**0.1**	**~ 20**

The different scenarios illustrated in Table 5-2 are compared per item presented in column 1.

TOTAL COSTS (direct effects – operators)

- As presented in Table 5-2, the infrastructure alternative causes the highest investment as well as operational costs. For the 445 km double tracks (one in each direction), around 19 milliard euros are required for construction and maintenance. Furthermore, new high-speed rolling needs to be purchased. Although for this alternative a smaller fleet is required (8 instead of 12 train sets), the high investment costs for an ICE cannot be covered.

- In the rolling stock alternative, the investment costs are with 20 million higher than in the reference case (column 5).

- Since in the network alternative a doubled frequency is offered, the required fleet is almost double as big, as in the reference case. The number of rolling stock is calculated based on the turnaround time of 1.75 minutes and the travel time until the border (see Appendix L). Thus, the investment and operational costs are also almost doubled, which explains the high costs compared to the reference case.

- The revenue alternative requires no other investments, than in the nil scenario. Therefore, the total costs are considered to be zero.

BENEFITS (direct effects – operators and passengers)

- Row 15 illustrates the operator benefits, which result from ticket sales. The infrastructure alternative provides with 330 million euros the highest revenues, over the period of 30 years. The fact, that the infrastructure alternative generates the highest ticket sales, is in line with expectations. As described in section 4.3.6, this alternative provides a significantly higher passenger growth then the remaining alternatives.

- The rolling stock alternative results in a lower revenue. However, in comparison to the reference case, operators gain 40 million more revenues.
- In the network alternative 10 million euro revenue are less obtained, than in the reference case. Thus, this value is negative. The outcome is in line with the model outcomes in section … . As in this alternative, the reduced number of served passengers is not compensated with the additional passenger due to the reduced travel time and increases frequency, the revenue is lower.
- In the revenue alternative, the fare is reduced by almost 23%. Although the number of passengers increases, the reference case provides higher income. Thus, the revenue is negative in this alternative (row 7).

EXTERNAL EFFECTS

- Since the mode shares are only known for the OD-pair Amsterdam-Berlin, this relation is solely compared for all cases. Row 31 shows the CO_2 reduction of cars, due to the modal shift of passengers from car to train. In row 32, the same is shown for air users.
- In line with the passenger increase, the highest reduction of external effects is achieved in the infrastructure alternative. Although the car is the dominant mode on the OD Amsterdam-Berlin, airplanes produce the highest amount of CO_2 per kilometre. The CO reduction due to train use, is thus for the airplane higher than for the car.
- In the rolling stock alternative, this situation is the other way around. More CO_2 costs are saved due to the improved train service.
- Due to rounding, the remaining alternatives perform equally.

PM ITEMS

- The PM items refer to effects which do influence the social welfare but are difficult to express in monetary ways (Bakker et al., 2009).
- With the improved service between the Netherlands and Germany, there will be an impact on the housing and job market (PM1, row 34). Furthermore, the service reliability (PM2), traffic safety (PM3), and landscape (PM4) will be affected.
- The effects are indicated in a qualitative way with plusses and minuses. The performance is shown in comparison with the reference case. For example row 34 refers to the landscape and nuisance impact, which is considered to be higher for the infrastructure alternative, due to the impact on the landscape, and the network alternative due to the increased frequency.

TOTAL BENEFITS (direct effects – operators and passengers)

- As expected, the infrastructure alternative provides significantly higher benefits (520 million euros), than the remaining alternatives and the nil scenario. With 70 million euros, the rolling stock alternative provides the second best result. The network and revenue alternative provide comparable outcomes.

NET PRESENT VALUE & BENEFIT/COST RATIO

- The rolling stock alternative provides the highest NPV of all alternatives. The infrastructure as well as the network alternative result in a negative value, due to high investment costs. As for the revenue alternative, the money saving for passengers are higher than the losses for the operators, the alternative provides a positive NPV of 20 million.
- The benefit/cost ratio (row 44) is the highest for the revenue alternative, as no investment costs are required. However, as the costs are zero for this alternative, the ratio is not applicable (as dividing by zero). For illustrative reasons, the costs are assumed to be one, which results in a ratio of approximately 20. The second best alternative is the rolling stock alternative with a ratio of 3.5. The remaining cases are not profitable in comparison to the nil scenario, as their ratio is smaller one (b/c <1).

5.7 Sensitivity analysis

From the societal evaluation, result the rolling stock and revenue alternative to be the most profitable one. As the calculations are based on a number of assumptions, the outcomes are tested on their sensitivity. This means that the input parameters are changed and the new obtained results compared. This however, is solely done for the two best performing alternatives.

Since there are no costs involved in the revenue alternative, the benefit side is considered only. Both, the direct effects for operators, as well as the money and travel time savings for passengers, are based on the number of passengers. In the modified LVM, passengers are calculated using the elasticities model (chapter 3). One might thus be interested in the performance of the rolling stock and revenue scenario in case the international elasticities are highly overestimated.

For the rolling stock alternative the travel time elasticity, for the revenue alternative, the fare elasticity is tested. In the reference case, the travel time elasticity is set with 0.6, and the fare elasticity with 0.8, according to the findings from chapter 3. By reducing the absolute value stepwise, the impact per service attribute (time, fare), is closer examined. The elasticities are diminished in steps of 10, 30, 50, 70 and 90 percent.

In Figure 5-1, the outcomes of the sensitivity analysis are presented. The elasticity values, as well as the entire calculation table are provided in Appendix L, Table L-1. The analysis shows that the reduction of the travel time elasticity reduces the NPV from 50 million, to around 30 million, over the entire project time. Similar is shown for the benefit/cost ratio. As the costs are not adjusted, the change is purely related to the revenue decrease. This explains that both graphs represent a similar shape. Overall, the analysis shows that the rolling stock alternative is even then profitable, if the international travel time elasticity is zero and the travel time reduction holds only for national travellers.

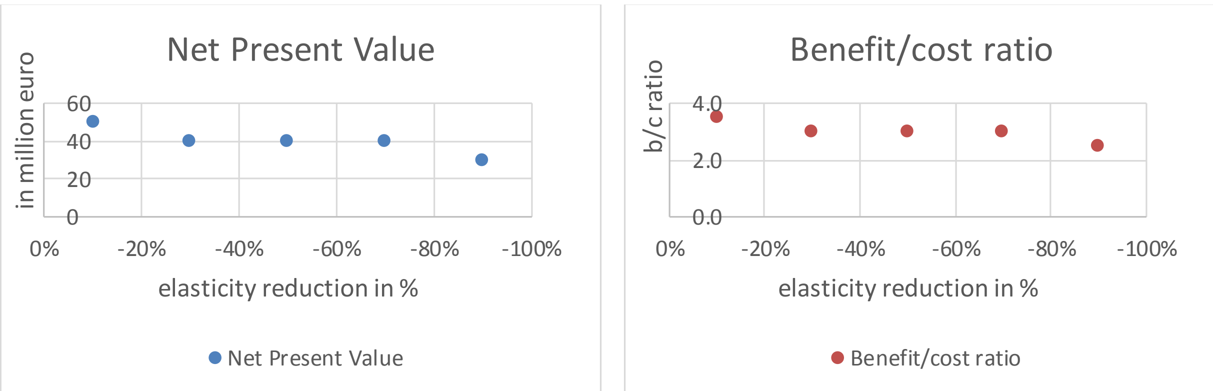


Figure 5-1: Sensitivity analysis, rolling stock alternative – NPV (left), benefit/cost ratio (right).

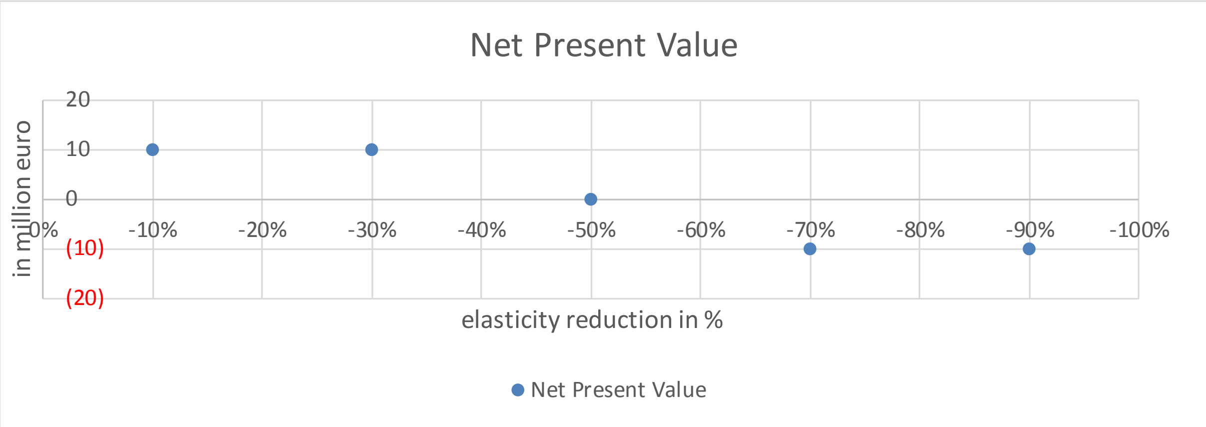


Figure 5-2: Sensitivity analysis, revenue alternative – NPV

The fare reduction in the revenue alternative applies for international passengers only. In Figure 5-2 the outcome of the sensitivity analysis for the revenue alternative is presented. The initial fare elasticity of 0.8 is reduced stepwise. As this alternative represents no costs, the equilibrium between the money savings for passengers and income losses for operators (compared to the reference case) are illustrated. At a reduction of 50%, or an elasticity value of 0.4, the money gains for passengers equal the revenue losses for the operator.

From the sensitivity analyses it can be concluded, that the revenue alternative is only profitable (positive NPV), in case the fare elasticity is at least 0.4. The rolling stock alternative performance profitable (b/c >1) even in case the international travel time elasticity is highly overestimated.

5.8 Outcomes per stakeholder – distribution effect

In the previous section, the alternatives are evaluated entirely. However, the alternatives provide different effects for different stakeholders, which were presented in section 2.4. Furthermore, the distribution effect is not calculated yet. Thus in this section, the costs and benefits are assigned to the respective stakeholders. In this way, the alternatives are re-evaluated based on the interests of the following stakeholders:

- Operator(s) – distribution effect
- Passengers
- Authorities

It is highlighted that the distribution effects and hence the costs and benefits per country, are in this section related to the operators NS and DB.

OPERATORS – distribution effect

The IC Berlin is currently operated over approximately one third (1/3) Dutch and two third (2/3) German territory. The 16 intermediate stops are distributed over a similar proportion, with 6 stations in the Netherlands and 10 stations in Germany. Therefore, the operational as well as investment costs are assigned according to this share. National and international passengers compose the revenue. As the German national demand is unknown, the revenues are considerably lower than in reality. From realised data in 2014 and the first half-year of 2015, the share between national and international revenue is derived for NS. The revenue evolves from 1/3 national and 2/3 international passengers. From this, revenue shares are calculated, with 14% national, and 29% international. The remaining 57% result from the high share of international revenue that is produced on the German side. As the infrastructure costs are actually paid by the infrastructure managers (and eventually authorities), the high investment costs for the infrastructure alternative are not incorporated.

NS

Excluding the high infrastructure investment costs, the infrastructure alternative provides the highest NPV from the perspective of NS. However, due to the still high costs for ICE rolling stock, the benefit/cost ratio (1.2) is lower than the one for the rolling stock alternative (2.8). Since the network alternative provides less revenue than the reference case, the benefits are negative. Hence, a negative cost/benefit ratio (b/c<1) is obtained. Similar hold for the revenue alternative. Thus for NS, the revenue alternative provides the most interesting performance.

Table 5-3: NS CBA

NS CBA		Infrastructure	Rolling stock	Network	Revenue
Costs NS		-120	-6	-80	0
NS national revenue	0.1	50	5	-1	-3
NS international revenue	0.3	95	11	-3	-7
Benefits NS		145	17	-4	-10
NPV	**[M€]**	25	10	-85	-10
B/C ratio		1.2	**2.8**	-0.1	-10

DB

Since for DB no national revenue is known, the NPV as well as the benefit/costs ratio are for almost each alternative negative. However, even without the incorporation of the national revenue performs the rolling stock alternative profitable for the DB, with a benefit/cost ratio of 1.8. However, if assuming that the revenue distribution for DB is comparable, to the NS revenue split, the expected benefits will be 280 million euros over the entire project time. With the cost 230 million euros, the alternative will perform profitable.

Table 5-4: DB CBA

DB CBA		Infrastructure	Rolling stock	Network	Revenue
Costs DB	**[M€]**	-230	-10	-155	0
DB national revenue	*?*	-	-	-	-
DB international revenue	0.6	190	20	-5	-15
Benefits DB		190	20	-5	-15
NPV	**[M€]**	-40	10	-160	-15
B/C ratio		0.8	**1.8**	-0.0	-15

PASSENGERS

In the societal evaluation, the revenue alternative scores the highest, due to two reasons. First, no investments costs are required. Second, the passengers experience high money savings (41 million euros). Although the passengers in the IC Berlin (leisure) are considered to be most sensitive towards fare adjustments, the infrastructure alternative provides with 188 million euros even higher benefits for passengers. This is mainly explained by the higher reduction. The fare is reduced by 23% for international trips only, whereas the ICE connection, provides 42% travel time reduction for all trips. Furthermore, the ICE connection is supposed to stop at every current station, which means that no passengers are lost due to skipped stops. Thus, from a passenger perspective, the infrastructure alternative provides the most interesting service.

Table 5-5: Passenger CBA

Passenger CBA		Infrastructure	Rolling stock	Network	Revenue
Money savings		-	-	-	40
Time savings		190	30	25	-
Benefits passenger	**[M€]**	**190**	30	25	**40**

AUTHORITIES

As authorities and governmental institutions, seek to maximise social welfare, the mainly refer to the societal evaluation. However, in the evaluation are some effects not monetised as the indirect effects or the impact on landscape (listed with PM items). Therefore, it is difficult to evaluate the alternatives from an authority perspective. However, the infrastructure alternative requires about 19 milliard euros. As this is paid by the infrastructure managers and eventually by authorities with taxes, this alternatives performs certainly the worse option. Furthermore, the negative impact on landscape and nuisance will be with this alternative the highest.

Since the rolling stock alternative, eventually results in the highest reduction of external effects, and a positive surplus for producers and consumers, authorities might be the most interested in this one.

Table 5-6: Governmental CBA

Governmental CBA		Infrastructure	Rolling stock	Network	Revenue
Costs NS	**[M€]**	-19,300	0	0	0
External effects		-	-	-	-
CO2 reduction car		5	1	0.2	0.1
CO2 reduction airplane		5	1	0.2	0.1
PM items	***€??***	-	-	-	-
Benefits NS		10	2	0.4	0.3
NPV	**[M€]**	-19,290	2	0	0
B/C ratio		0.0	**2**	0.4	0.3

5.9 Reflection on outcomes

Due to the model limitations when modelling frequencies (see section 4.3.3), the international supply side is overestimated by a factor three (3). In order to compensate this overestimation, the input demand for 2024 is adjusted equally. This frequency "trick" leads to additional service during peak hours, which is especially for national travellers attractive. However, it is difficult to exactly determine the amount of overestimation. Nevertheless, as the error, occurs in each alternative, also in the reference case, the error is neglected.

In contrast to the overestimation, the demand is underestimated over the time. As presented in chapter 3.1, demand is extrapolated over the coming ten years. In general a growth in trip distances is found (Violland, 2011). Therefore, we expect a growth of demand over the entire project time. However, this effect is not covered by the SCBA. Another aspect, which reveals in the underestimation of benefits, is presented by the lack of German national demand. For a complete evaluation of all alternatives, the German demand needs to be incorporated.

The sensitivity analysis investigates an uncertainty of predefined demand elasticities. The analysis is especially interesting for pessimistic elasticity values. In the worst case scenario, the elasticity is zero and hence no additional passengers are gained with a service improvement. The analysis shows that the rolling stock alternative operates beneficially, even if no additional passengers are gained. However, the benefits are less compared with the reference case.

Finally, the modal shift for the connection Amsterdam-Berlin is presented for one single connection. The external effects are higher, if the complete multi modal demand is incorporated. However, as the travel time gains for the infrastructure alternative are the highest, the reduction of externalities will be the highest for this alternative. Nevertheless, the cross-elasticities are calculated based on the mode shares for the OD-pair Amsterdam-Berlin. In case the externalities for the entire network shall be calculated, new cross-elasticities need to be determined. For OD-pair without access to an airport, the relation will be significantly different.

5.10 Conclusions – societal evaluation

This chapter provides the final step of the research framework (see section 1.5), the evaluation. Since the objective of public transport is based on maximising social welfare, a societal evaluation is chosen. The outcomes influence both; future operational as well as strategic decisions and hence closes the design cycle.

The insight gained from the social evaluation of future services helps to answer the final sub research question:

What are the effects of a future service between Amsterdam and Berlin?

In the previous chapter, the demand effects are modelled, which are one part of the transport market. However, there are other stakeholders, which are affected by an adjusted future service between Amsterdam and Berlin. Thus, the evaluation is split into two types. The first evaluates each alternative entirely. The second evaluation concentrates on the different stakeholder interests. All outcomes are summarised in Table 5-7:

Table 5-7: Summarised evaluation outcomes.

			ALTERNATIVES			
			Infrastructure	**Rolling stock**	**Network**	**Revenue**
	Societal CBA					
	Net Present Value	[M€]	-19,130	***50***	-210	***20***
	Benefit/cost ratio		0.0	***3.5***	0.1	***~ 20***
	DIRECT AND DISTRIBUTION EFFECT					
	Operator CBA					
NS	NPV	[M€]	25	***10***	-85	-10
	B/C ratio		1.2	***2.8***	-0.1	-10
DB	NPV	[M€]	-40	***10***	-160	-15
	B/C ratio		0.8	***1.8***	-0.0	-15
	DIRECT EFFECT					
	Passenger CBA					
	Benefits passenger	[M€]	***190***	30	25	40
	EXTERNAL (AND INDIRECT) EFFECT					
	Governmental CBA					
	NPV	[M€]	-19,290	***2***	0	0
	B/C ratio		0.0	***2***	0.4	0.3

The evaluation (Table 5-7) shows for the rolling stock alternative the highest NPV, with around 50 million euros over the entire project time of 30 years. As the alternative reveals in high benefits compared to low investment costs, the benefit/cost ratio (B/C ratio) is bigger one. Hence, the alternative is profitable. The NPV of the revenue alternative is with 20 million euros, lower than the rolling stock alternative. However, due to its zero investment costs, the alternative has a higher B/C ratio than the rolling stock alternative.

Nevertheless, from an economical point of view, displays the revenue alternative no real option. This results from the operator CBA. For both, the NS and DB provides the reduction in fare a reduction in income. Even though, the absolute number of international passenger increases, the loss due to a 23% fare decrease cannot be covered. For the operators, the rolling stock alternative provides the only attractive option.

From a passenger perspective, the infrastructure alternative provides the highest positive effects, with 190 million. As each alternative provides an improvement, they are all positively evaluated. Nevertheless, in the network alternative many passengers are worse off, as they lose direct access to the IC Berlin. This effect is mentioned with the PM items but not closer quantified.

Although the highest modal shift and thus reduction of CO emissions is achieved by the infrastructure alternative, authorities (governmental CBA) prefer the rolling stock alternative. The high infrastructure investment cost make the infrastructure alternative unattractive (also taxpayers).

Overall, there are three major effects, which contribute to the evaluation of international projects:

- Direct operator effect - Distribution effect
- Direct passenger effect
- External effects

The societal evaluation helps to incorporate all effects, in order to find the best performing international service between Amsterdam and Berlin. It is highlighted that the performed evaluation underestimates the benefits, due to the following aspects:

- German national benefits are missing (not incorporated).
- Externalities (CO_2 reduction) only for the OD-pair Amsterdam-Berlin determined.

6 Conclusion, discussion and recommendations

The final chapter answers the main research question in two steps. First, the answers to the sub research questions are summarised, which are given at the end of the respective chapter. Afterwards, in the second section, the main research question is answered. Furthermore, the section incorporates generic conclusion regarding the case, the framework used and the international transport in general. The third section provides a discussion on the conducted study. The last two sections incorporate recommendations for further research and for NS.

6.1 Sub conclusion

This thesis answers the main research question – *"How to evaluate international train service alternatives?"* - with a twofold approach. First, a theoretical framework is established (presented in section 1.5). Second, the usefulness of this framework is tested by applying the case of IC Berlin on each step of the framework. In this section, a summarising overview of the answers to the sub research questions is presented.

The first step of the framework investigates the supply side of the international market. Therefore, the question is stated as: What defines international passenger train transport networks and what are the characteristics of the Dutch-German network?

Definition international train networks -International train networks are located on the highest city hierarchy, which is described with a network level A. In literature, among others, two thresholds are presented for international train networks. Firstly, the service distances have to be more than 300 km. Secondly, the transportation speed is around 160 km/h.

Network characteristics Netherlands-Germany - Due to the speed limitation of 140 km/h and the distances between intermediate stops on the Dutch network, the international services to Germany do not fulfil the speed criteria. Moreover, due to technical differences such as overhead voltages or the safety system per country, a continuous operation is difficult. These issues are solved by either providing multi current technique, or conducting a locomotive change at the border. Furthermore, adjustments of international networks or services require the cooperation with other operators. However, issues as confidentiality or competition diminish access to data, which is required to evaluate the service entirely (including national demand for related countries). Hence, with the increasing amount of stakeholders involved, an international operation becomes more complex.

Demand characteristics (NL-DE)

The international passengers are distributed over the services. One third of the international passengers travel with the ICB, whereas two third travel with the ICE. The stations Amsterdam and Utrecht are the most attractive nodes in the Dutch network for international connections. In Germany, the attractiveness is wider spread over the nodes Köln, Düsseldorf, Berlin and Frankfurt. Under the most requested destinations are also secondary stations. These are stations, which are not served by the current services directly (e.g. Rotterdam and Hamburg). Furthermore, the mode shares are presented in this study for dedicated OD-pairs. The train share is 30 percent for the OD-pairs Amsterdam-Berlin, Amsterdam-Frankfurt and Amsterdam-Köln. Car has the highest share, however this share decreases for longer OD distances. The airplane share varies between 10 and 20 percent and is the lower for short OD distances. The bus share is relatively equal with 10 percent.

With the knowledge over the current demand, essential insights of demand behaviour are missing. These however, are required to answer the next sub research question: How does demand react to service changes in the Dutch-German market? The question is subdivided into part a) and b). The first part gives a general overview of the modelling approaches available for transport demand modelling. Based on the chosen model approach, the second part defines the demand parameters.

a. How can (train) demand be modelled?

Based on literature and practical insights, three transport models are distinguished, namely multi-stage, direct demand and the elasticity model. Each provides different advantages and disadvantages. The first requires much input data but is suitable for modelling a new service (e.g. new freeway). The second model is rather difficult to determine mathematically, since little constraints are provided. However, it but provides for interurban transport the better result compared to multi-stage models. The last model however, provides the most advantages. Elasticities are used as weightings of demand due to changes in service (endogenous) or socio-economic context (exogenous). In literature, they are derived from multi-stage or direct demand models to illustrate demand behaviour (e.g. cross-elasticities from logit models). In practice, the model type is preferred over the others due to the straight application and the low amount of input data required (e.g. ticket sale data). Therefore, the elasticity model is chosen.

b. What are the demand parameters for the Dutch-German market?

Since demand determines the performance of alternative services, this question is investigated extensively. The answer is found with a twostep approach. At first, literature was reviewed on train demand elasticities. Since elasticities depend on the service and socio-economic context, the literature that is found, is filtered using an assessment framework. From the relevant literature, the following insights are gained:

Trip purpose – In literature mostly two types of trip purposes are distinguished: Business and non-business passengers. Passenger travelling for business are more sensitive for time related service attributes, leisure travellers are more affected by price attributes. Another attribute found in literature is frequency, which might be translated into waiting time. However, passengers experience frequency as less important than the other two service attributes.

Service changes – Passenger react stronger to service worsening than service improvements (e.g. fare changes). This so-called demand asymmetry however, holds mainly for short-term adjustments. In long-term studies, the effects assimilate.

Elasticities – In literature, elasticities are derived from different models and are based on different markets (e.g. business passengers in Canada). The elasticity ranges vary highly between 0.6 (inelastic) and 1.8 (elastic) for one service attribute and trip purpose. For this reason, the found elasticities are presented to experts. With a semi-structured interview, four experts in the field of train demand modelling were interviewed. Besides the question on demand elasticities, the experts ware asked on more general issues related to long-distance transport demand between the Netherlands and Germany. The following main insights are gained:

- The expected annual growth for the Dutch-German market is between 0.5 and 2 percent.
- The cross-border effects for the Dutch-German long-distance market can be neglected. This implies that passengers do not incorporate the border, when choosing a (leisure) destination.
- The travel time elasticity increases with increasing distance travelled.
- Cross-elasticities depend on the available mode shares.

From literature review and the expert interviews, the final demand parameters for the long-distance transport market Netherlands-Germany are concluded.

	Train		Air		Car	
Rail service attributes	Business (B)	Non-Business (NB)	Business (B)	Non-Business (NB)	Business (B)	Non-Business (NB)
Travel Time	**-1.0**	**-0.6**	0.3	0.1	0.3	0.1
Fares	**-0.5**	**-0.8**	0.2	0.2	0.2	0.2
Frequency	**+0.4**	**+0.2**	-0.1	-0.1	-0.1	-0.1

With the insights of supply and demand characteristics of the international market, the following framework step is applicable: modelling alternatives. This step gives the answer to the following sub research question: How can service alternatives be determined? Similar to the previous question, the answer is split in three parts.

a. What are the alternatives for the IC Berlin?

In order to find service alternatives in a structured way, the relevance tree is applied to the case study. Excluding the irrelevant measures from the decision tree results in four alternatives. Each alternative incorporates one or more measures. The measures are translated into travel time, fare or frequency improvements, based on the current situation. For each alternative a conceptual calculation was conducted, which results in the following quantified improvements:

Infrastructure alternative – New and improved high-speed infrastructure enables speeds up to 300 km/h. With the increased speed, the current travel time is reduced by 42% (from 6.3h to 3.7h).

Rolling stock alternative – Faster fleet with multi current technique enables a continuous operation at the border. With the elimination of 10 minutes waiting time at the border, the timetable needs to be adjusted. A calculation in the Dutch side reveals in a travel time decrease of 9 minutes. With the assumption that similar slack is incorporated in the German timetable, the total travel time decrease is about 30 minutes, or 8% (from 6.3h to 5.8h).

Network alternative – With a new route over the Hanzelijn and the reduction of intermediate stops from 16 towards solely three, 35 minutes of the current travel time between Amsterdam-Berlin are reduced. In addition, the service frequency is doubled to one time per hour.

Revenue alternative – In this alternative, the international fares are reduced by 23%.

With the presented alternatives, the next sub question is formulated:

b. How can these alternatives be tested on their performance?

For national services, NS uses modelling tools to test their efficiency in terms of demand (VISUM), in terms of timetable feasibility (DONNA) or in terms of an optimised network (LVM). However, in order to evaluate entire international services, such tools are missing. However, with the extension of the LVM towards the German network and the implementation of demand elasticities, the predefined alternatives can be tested as a whole. Since the LVM is restricted to internal use, basic criteria are concluded that a similar testing tool needs to fulfil:

National – Basic assignment model to determine the demand for different service alternatives. Herewith, the national supply side and demand side need to be integrated.

International – Extension of the network, in terms of links and node. Furthermore, the international services, as well as the current demand need to be introduced.

- Preferably, the national demand of the other country is known and integrated.
- Introduction of the international rolling stock types, their costs and respective speeds.
- Introduction of an international demand elasticity model (use of the elasticities determined before).
- Introduction of other modes, and their correlation with train usages.

With the international setting of the LVM, the tool is used to test the alternatives. The outcomes shall provide an answer to the next question:

c. Which service alternative provides the highest demand?

For international transport demand, the alternatives are tested with the elasticities for non-business passengers, since this is currently the biggest user group of the IC Berlin. For the national demand, the predefined generalised elasticity value is used. Modelling the alternatives shows that the infrastructure alternative provides the highest increase in passengers and passenger kilometres. As the alternative provides the highest travel time improvement, the outcome is in line with expectations. However, due to the mixed use of international and national passengers, the testing reveals in different outcomes for the remaining alternatives than initially expected. Thus, from the modelling section of this study the following aspects are concluded:

LVM – The use of a calculation tool, as the LVM, enables the user to get a better insight into the impacts of different alternatives. Especially for international services, where national and international markets need to be modelled, the impacts of service adjustments are not always easy to foresee (as for instance in the network alternative).

Alternatives – As the case study illustrates, the percentage improvements may lead to wrong assumptions on the outcomes. This relates to both the elasticities and the service attributes. The revenue alternative is a good example, which shows this effect. Although the fare elasticity suggests the highest impact on the current demand (elasticity = -0.8), a fare reduction by 23 percent, does not lead to the highest increase in passengers. Another example is the network alternative, which reveals a smaller increase compared to the reference situation/alternative. Thus, especially for service adjustments, which affect only a dedicated group of passengers, the tested alternatives show interesting outcomes.

With the calculated demand per alternative, the final sub research question can be answered: What are the effects of a future service between Amsterdam and Berlin? In literature, the objective of public transport is formulated as the maximisation of social welfare. This implies the maximisation of producer and consumer surplus. In order to achieve this, and to express the effects of each alternative, a societal cost-benefit analysis is conducted for a project time of 30 years. The evaluation reveals the best performing alternatives:

Rolling stock alternative – With a Net Present Value of 50 million euros and a benefit/cost ratio of 3.5, the rolling stock alternative performs the best. The alternative improves the running time by 8% compared to the reference case. This calculation is based on the assumption that interoperable rolling stock is used and the travel time in each country can be reduced by about 10 minutes. This results in a total travel time reduction of 30 minutes, for a trip between Amsterdam and Berlin.

Revenue alternative – The second best alternative is the revenue alternative. Due to zero investment costs, the alternative provides a higher benefit/cost ratio than the rolling stock alternative. However, an analysis of the outcomes for the four stakeholders NS, DB, passengers and authorities shows losses for the operators. Since the research goal of this study is to provide an alternative for the IC Berlin, which is at least cost-covering, the revenue alternative provides no real option. Furthermore, the losses of 20 million for the operators will have a negative impact on the employees and the economic healthiness of the company, which might eventually lead to even higher losses than provided by the societal evaluation.

6.2 Main conclusions

With the answers of all sub research questions, the established framework is successfully tested on its usefulness. Thus, the main research question is answered as follows:

With the stepwise application of the presented framework, including the application of the investigated demand parameters, future international passenger train services can be modelled. These insights provide input for a societal evaluation. Based on the evaluation outcomes, decision-makers are supported to make strategic design choices. In case of an implementation, tactical and operational design choices are affected.

The conclusions from this study are split in three parts, namely framework related, case study related and general conclusions for the international train transport.

Conclusions - IC Berlin

Due to the reason that every framework step is tested with the IC Berlin service, an in-depth case study is provided. However, the investigation on the first two steps, the analysis of the supply and the analysis of the demand side provide insights on the long-distance market Netherlands-Germany. Thus, information over the network, services or transportation demand considers also the intercity express (ICE) to Frankfurt. From the study conducted, the following conclusions are made:

Network – In literature, international public transport networks are defined with a service distance of 300 km and transportation speeds of 160 km/h. Due to the speed limitation of the Dutch network to 140 km/h, the regarded network does not fulfil the second characteristic. Thus, the ICE service, which is operated with high-speed rolling stock, performs under its technical abilities. In addition, the network requires different safety systems and voltages, which make continuous transportation challenging.

Demand – From literature and the interview with experts, for the Dutch-German long-distance market, an annual growth between 0.5 and 2 percent is predicted. The trend is related to endogenous factors as for instance decrease in population or increasing GDP. However, due to the applied growth factor method, a linear growth for the entire market is suggested. Especially for the IC Berlin serving cities of different sizes, the demand might grow slow for certain OD-pairs (lower bound). In contrast, agglomerations with an increase in population might reveal in a growth close to the upper bound of the range. Due to the mix of big and small stations along the line and due to a study conducted in 2011 for international train networks, a moderate growth of one percent per year is assumed.

Barrier effects – Studies on barrier effects explain that demand decreases towards the border. Discounting this effect leads to overestimated benefits for international transport projects. However, from the investigation we conclude that European borders do not significantly affect leisure passengers. This is mainly explained by the missing border controls. Thus, for leisure passengers using the IC Berlin and ICE Frankfurt, cross-border penalties are not incorporated.

Conclusions – Methods

Framework – The suggested theoretical framework incorporates six steps, namely *supply*, *demand*, *demand parameter*, *alternatives*, *modelling alternatives* and the final *evaluation* step. By following these steps, decision-makers are able to evaluate service alternatives. In this study all steps are followed sequentially. Since the application of the framework, revealed in the evaluation of different service alternatives, the method is considered as successfully tested. In case other Dutch-German services are tested, solely the last three framework steps need to be applied. The first three are covered by this study. Moreover, for services with demand characteristics comparable to the Dutch-German train market, the demand parameter step is not required. Here the determined elasticities can be applied. This however holds only, if in the new research setting an elasticity model is applied. Nevertheless, the application of the framework steps is constrained to the access of data. Especially for the international and foreign national demand (other country), data might be missing. Thus, the alternatives can be solely tested on the available demand. The demand for the service (national, international and foreign national) need to be approximated. Furthermore, for the determination of alternatives, timetable information of the foreign country is desired. Alternatives, which suggest travel time reduction might then be directly tested. Other service related aspects are technical information and infrastructure speeds, acceleration factors, etc. Hence, for the application of the framework it is concluded that the framework enables decision-makers to evaluate international lines in a systematic way. With the research on international demand elasticities, and their implementation into a calculation tool (LVM), international train services can be quantified entirely.

LVM – The use of a calculation tool as the LVM enables decision-makers to quantify international train service alternatives. The quantification of alternatives shows that improvements, such as the reduction of travel time, do not necessarily result in an increase of passengers (e.g. network alternative). Thus, counter-intuitive outcomes are observed during the study. Therefore, we conclude, that the use of a software-supported model is desired for every service, which is used by more than one market. In the here conducted study, national and international markets behave differently. Moreover, the presented alternatives require service adjustments, which might be experienced by a dedicated group of travellers only (e.g. price reduction for international tickets). For this reason, the quantification of alternatives requires model support.

Conclusions - International train transport

Stakeholder – From the stakeholder analysis for the Dutch-German market, it reveals that the number of stakeholders increases. For a service through two countries, there are for instance two national operators, infrastructure managers and various regional and national authorities. Since these stakeholders have a high level of power and interest, they have an impact on the evaluation process (operators) and a later implementation process (managers and authorities). This study shows the complication, by providing a societal cost benefit analysis. Nevertheless, for international studies with two and more operators, the simultaneous insight into national markets is complicated or even impossible. These insights are desired, as the optimal service for all operators can be determined (e.g. with the use of the LVM). However, operators do not share this confidential information as it relates to revenues and they fear competition. Furthermore, sharing information might be prohibited with the antitrust regulation by the European commission (cartel law). However, this aspect is not closer examined in this study. A solution to the incomplete information would be a European operator. In this way, the ownership is assigned to one party. This provides the advantage that services are improved entirely. Furthermore, projects might be faster realised, since all information is accommodated at one party. On the contrast, this implies a monopoly, which requires strong regulations. Thus, in conclusion international service adjustments face challenges due to incomplete data accessibility.

National vs. international markets – International train services are comparable to national services in case they are both long-distance. From the here conducted study we conclude that the destination choice for leisure activities within Europe is independent from borders. This is a qualitative conclusion and derived from the expert answers. We reason this with eliminated border controls for the European Union and the similar currency. Nevertheless, this qualitative conclusion should be tested with a transport survey for long-distance trips.

Trip purpose – The number of leisure trips is high for long-distance trips. Dependent on the attraction potential as leisure destination, the majority of passengers use the service for leisure purposes. However, for markets with different socio-economic characteristics, car ownership or the accessibility to air transportation might be reduced. Thus, other user groups will be more represented among train passengers.

Sensitivity per trip purpose – Leisure passengers are the most sensitive towards fare, business passengers towards time related services attributes. This result from empirical studies, which are the base for the literature review. Furthermore, the experts supported these insights. The travel time sensitivity increases with an increase in distance. Thus, travel time improvements of 10% have a higher impact on a trip of 6 hours, than on a trip of 10 minutes.

Cross-elasticities and limitations – For this study, the cross-elasticities are established based on the train probability. Thus, passengers diverting from train due to a service worsening, are distributed over the remaining modes according to their shares. With this approach, an equal proportional distribution over the modes is conducted. Hence, the car as the dominant mode in the network, will gain the most passengers according to its share. In literature, cross-elasticities are derived from logit models. The multinomial logit (MNL), which is used by the experts, is limited to the property of "independence of irrelevant alternatives" (IIA). This property implies a proportional distribution of passengers over all alternatives. Thus, the application of a MNL to determine cross-elasticities, will lead to comparable outcomes. However, since the modal split varies per OD-pair, the cross-elasticities will vary. Thus, applying cross-elasticities over an entire line is difficult, since the elasticities need to be determined per OD-pair. Otherwise, passenger will opt for airplanes, were no airplanes are offered.

6.3 Discussion

Since the international train transport and demand modelling is barely investigated, many decisions are made throughout the study to scope the work. This section thus elaborates on the assumptions, models and the used method, to approach this subject.

Elasticities – One of the core parts of this study concentrates on the determination of demand elasticities for international services. This is based on literature and expert opinions. Since the literature review is conducted first, the service attributes travel time, fare and frequency are derived. However, another approach, as consulting the experts first, or surveying passengers, might lead to more service attributes. Nonetheless, the insight of the three presented service attributes represents a first step. Furthermore, one should bear in mind that the determined elasticities result actually from ranges. For this study, the ranges are diminished to single values. However, for other studies the values might slightly vary and should thus be used in a generic way.

The relevance tree – In order to define different alternatives, the relevance tree is applied. This leads to a wide range of different alternatives, which was one of the requirements of this study. The selection of the final measurements within one alternative is based on the case study. However, there are other approaches originating from systems engineering, which are interesting for an extensive approach. One example is the 5-step Dym and Little design process. In this model, the generation of alternatives results from a detailed study on the problem definition, where consumer and producer requirements define the design criteria. Nevertheless, this is a rather time intense approach, with a level of detail, which was not desired for this study

SCBA – For the evaluation step, the societal cost-benefit-analysis is chosen. From this evaluation, one might also choose for the revenue alternative, which provides a benefit of 20 million and zero investment costs. However, the research goal is stated with *"Determine a service alternative for the passenger train connection Amsterdam-Berlin from upon 2024, which is at least cost-covering"*. Thus, the research goal is also achieved with a cost-benefit analysis only. However, due to their service distance (300 km and more) international services are considered as cost intense. A societal evaluation might help to gain subsidies. Furthermore, the insights helps when negotiating with different stakeholders.

Research design – The presented framework is tested with the IC Berlin. This case represents a low operational speed and a mixed function of national and international passenger transport. However, there might be other services, which provide different service characteristics or operate on different markets. For the Thalys, running between the Netherlands and France, the approach might be more difficult. First, the service affects three countries (also Belgium). Second, the national use is different, as a supplement is required. Third, the mode shares and thus cross-elasticities might be different. However, in case the trip purposes are known for the international passengers, the established demand elasticities might be used to obtain a first rough estimation on demand changes (when adjusting the current service). Nevertheless, with the Thalys, a seat reservation is obligatory. This is an aspect, which is not investigated yet. Thus, with the framework application on other cases, decision-makers need to bare the following things in mind:

- A different case might lead to a different set of data.
- The demand and supply side need to be approached in a different way, if operators do not share their information on passenger numbers and characteristics.
- Different service characteristics might be of influence. One example is the seat reservation obligation for the Thalys service.

6.4 Recommendation for further research

The two previous sections provide main conclusions and some reflections on this study. However, since the field of international train transport little is investigated, this section lists some recommendations for further research.

Framework - The presented framework is tested with one single case study. In a following step, we recommend to apply the framework to a number of services and countries. From these studies then a cross-comparison can be conducted to provide more insights of international transportation in general.

Bus service – The long-distance bus service is according to our information, not investigated. However, with a share of almost 10 percent, the bus obviously creates demand. Another development is the ridesharing service, facilitated by blablacar.com and other websites. Both are characterised as cheap and point-to-point services. These trends are barely interesting for railway operators, as young and low budget travellers are not their main target group. However, in relation with high fuel prices and congestion, policy-makers might be interested in these trends.

Model type – In this study, the demand is modelled using demand elasticities. The use of elasticities provides only an aggregated estimation of the demand over the entire line. However, there is no distinction between different OD-pairs. A more sophisticated approach is the use of a gravity model, which uses the production and attraction potential per OD-pair. In this way high demanded OD-pairs as for instance Amsterdam-Berlin, will grow more than a lower demanded OD-pair as Almelo-Bad Bentheim. Thus, in case decision-makers are willing to differentiate per OD-pairs, we recommend using an sophisticated model as for instance the gravity model.

Mode – choice – In this study, mode choice is modelled with cross-elasticities. This insight is mainly used for the later evaluation of externalities, or to be more specific, the determination of CO_2 reduction. However, in case decision-makers are interested in mode choice for long-distance trips, it is recommended to use a more sophisticated model, as for instance a logit or any advanced logit model (e.g. nested, mixed, etc.).

6.5 Recommendation for NS

This section is split into three parts. The first describes recommendations for NS related to the IC Berlin. The second focusses on recommendation regarding the established LVM. The third provides recommendations that are more general.

Timetable check – From this investigation, the rolling stock alternative provides the best result. However, the alternative is based on the assumption that also on the German side the current travel time can be decreased by 10 minutes. In a next step, this outcome should be presented to DB. Even though the German national market will profit from a 10-minute improvement, DB might not agree on a timetable adjustment. In this case, it is recommended to recalculate the alternative with a lower travel time gain (20 minutes, instead of 30 minutes). Additionally, the societal evaluation needs to be conducted again.

Revenue management – The investigation reveals that leisure passengers are the biggest traveller group and are most sensitive towards fare related attributes. In this study, a revenue decrease by 23 percent was tested and defined as non-profitable for NS. This outcome is not surprising, since the used fare elasticity is lower than one. However, in case later investigation will provide a fare elasticity bigger than one, fare reductions should be reconsidered. Moreover, in line with the found elasticities, it is recommended to increase the average revenues slightly, since the demand behaves inelastic (smaller than one). However, in case of a fare increase we recommend to improve service reliability and investigate more the available alternatives, e.g. airplane and car.

Supplement – Finally, it is recommended to investigate the effects of introducing a fare supplement for national use from 2024. With an adjusted service, e.g. operation of new rolling stock, the national fare might be increased with a supplement as done for the ICE Frankfurt. It is assumed that the demand behaves inelastic towards supplements, since many passengers own a travel card. Thus, a revenue increase might result from this measure.

International Lijnvoeringsmodel

Operational costs - The international LVM represents a calculation and optimisation tool for the commercial evaluation of services on a network. With its focus on the financial performance, the model excludes infrastructure limitations. Furthermore, for the German rolling stock or personnel costs, no capacity limitations are incorporated. In order to make the international setting more feasible, it is recommended to imply capacity constraints and to provide for the use of international personnel and fleet a penalty as it is applied in the national setting.

Frequency limitation - The successful model extension of the LVM shows that services of foreign countries are insertable. However, due to the national model setting, flaws as the frequency limitation are encountered. Due to the fact, that only integer frequencies can be modelled, the trick is used to increase the demand side by a similar factor, as the frequency is increases (supply side). However, this trick does not fully balance the additional supply. Hence, the effect results in a higher attraction of the national demand than expected. This effect is for instance illustrated during the optimisation. For future applications, it is strongly recommended to eliminate the frequency programming error.

Demand matrix – Due to the high amount of passenger travelling for leisure (90%), the elasticities for non-business passengers are applied for the entire international OD matrix. Nevertheless, for other study cases a mixed used of trip purposes might be desired. In order to forecast mixed trip purposes, we recommend working with two, instead of one demand matrix as input file. Thus, one OD matrix per trip purpose.

General

Elasticities – Since the demand elasticities are derived from literature, the service attributes travel time, frequency and fare are closer examined. However, from the recent NS customer survey it reveals that the IC Berlin target group chooses the train among others, due to comfort. Therefore, we recommend investigating elasticities related to service attributes, as reliability or comfort. These attributes might lead to a higher attraction on passengers than the investigated ones. Thus, higher elasticities might result for these attributes.

Less stops – From upon 2017, the Eurobahn between Hengelo and Bielefeld will operate once per hour. Besides Hengelo, the line serves stops as Bad Bentheim, Rheine and Osnabruck. With the use of interoperable rolling stock, the IC Berlin might skip intermediate stops as Bad Bentheim and Rheine, since the Eurobahn serves them. However, in this case the transfers require a special attention when taking operational decisions as the generation of a timetable.

References

Anthony, R. N. (1965). *Planning and Control Systems: A Framework for Analysis [by]*. Division of Research, Graduate School of Business Administration, Harvard University. Retrieved from https://books.google.se/books?id=4EeyAAAAIAAJ

Bakker, P., Zwanevel, P., Berveling, J., Korteweg, J. A., & Visser, S. (2009). *Het belang van openbaar vervoer vervoer - de maatschappelijke effecten op een rij*.

Balcombe, R., Mackett, R., Paulley, N., Preston, J., Shires, J., Titheridge, H., … White, P. (2004). The demand for public transport: a practical guide. *TRL Report TRL593*. http://doi.org/10.1016/j.tranpol.2005.12.004

Bhat, C. R. (1995). A heteroscedastic extreme value model of intercity travel mode choice. *Transportation Research Part B: Methodological*, *29*(6), 471–483. http://doi.org/10.1016/0191-2615(95)00015-6

Cascetta, E., & Coppola, P. (2014). High Speed Rail (HSR) Induced Demand Models. *Procedia - Social and Behavioral Sciences*, *111*, 147–156. http://doi.org/10.1016/j.sbspro.2014.01.047

CBS. (2014). CBS StatLine - Lengte van spoorwegen; spoorwegkenmerken, provincie. Retrieved August 21, 2015, from http://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLNL&PA=71024ned&D1=0-1,5,9,13,17,21&D2=0-4&D3=a&D4=a&HD=090330-1650&HDR=G2&STB=G1,T

Chang, Y. H., Yeh, C. H., & Shen, C. C. (2000). A multiobjective model for passenger train services planning: Application to Taiwan's high-speed rail line. *Transportation Research Part B: Methodological*, *34*(2), 91–106. http://doi.org/10.1016/S0191-2615(99)00013-2

CIE4811. (2008). chapter 5 . Timetable Design, 85–116.

DB BAHN. (2015). Retrieved October 6, 2015, from http://reiseauskunft.bahn.de/bin/query2.exe/en?ld=15031&country=DEU&seqnr=1&ident=cd.01207431.1444120183&rt=1&newrequest=yes&&country=GBR

Deutsche Bahn. (2015). Trassenpreise kalkulieren. Retrieved October 6, 2015, from http://fahrweg.dbnetze.com/fahrweg-de/produkte/trassen/trassenpreise/trassenpreisauskunft_tpis.html

European Commission. (2013). The Core Network Corridors, (July), 1–12. Retrieved from http://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/brochures_images/b1_2013_brochure_lowres.pdf

Forschungs-Informations-System (FIS). (2011). Fahrzeugrevolution. Retrieved September 14, 2015, from http://www.forschungsinformationssystem.de/servlet/is/342753/

Frei, A., Kuhnimhof, T., & Axhausen, K. W. (2010). Long-Distance Travel in Europe Today: Experiences with a New Survey. *Transportation Research Board, Swiss Federal Institute of Technology Zurich*, 16. http://doi.org/http://dx.doi.org/10.3929/ethz-a-005976787

Gebiedsontwikkeling per regio | Ruimtelijke ordening en gebiedsontwikkeling | Rijksoverheid.nl. (n.d.). Retrieved August 21, 2015, from http://www.rijksoverheid.nl/onderwerpen/ruimtelijke-ordening-en-gebiedsontwikkeling/gebiedsontwikkeling-per-regio

Goeverden, D. C. D. Van. (2007). Train attractiveness in European long distance travel. *11th WCTR 2007*.

Guis, N., Keizer, B. De, & Nes, R. Van. (2012). Lijnvoering van de toekomst voor het Nederlandse spoornetwerk. *Tijdschrift Vervoerswetenschap*, (3), 84–98.

Intraplan Consult GmbH, & sma. (2011). Railteam Study Network 2020.

Keizer, B. De, Fioole, P.-J., & Wout, J. van 't. (2013). Optimalisatie van de lijnvoering op Railnetwerken. *Colloquium Vervoersplanologisch Speurwerk*, (november). Retrieved from http://www.cvs-congres.nl/cvspdfdocs_2013/cvs13_067.pdf

Knowles, R. D., & Matthiessen, C. W. (2009). Barrier effects of international borders on fixed link traffic generation: the case of Oeresundsbron. *Journal of Transport Geography*, *17*(3), 155–165. http://doi.org/10.1016/j.jtrangeo.2008.11.001

Koppelman, F. S., & Wen, C. H. (2000). The paired combinatorial logit model: Properties, estimation and application. *Transportation Research Part B: Methodological*, *34*(2), 75–89. http://doi.org/10.1016/S0191-2615(99)00012-0

Luftlinie.org. (2015). Retrieved October 6, 2015, from http://www.luftlinie.org/

Mandel, B., Gaudry, M., & Rothengatter, W. (1997). A disaggregate Box-Cox Logit mode choice model of intercity passenger travel in Germany and its implications for high-speed rail demand forecasts. *The Annals of Regional Science*, *31*(2), 99–120. http://doi.org/10.1007/s001680050041

Muconsult, B. V. (2015). Literatuurstudie tijd- en convenience gevoeligheden openbaar vervoer. *Unpublished*, 1–83.

Nes, R. Van. (2002). Design of multimodal transport networks: A hierarchical approach. In *Proefschrift* (p. 287). http://doi.org/90-407-2314-1

NiederlandeNet. (2015). Retrieved September 8, 2015, from https://www.uni-muenster.de/NiederlandeNet/aktuelles/archiv/2015/februar/0224bahn.html

Ortúzar, J. de D., & Willumsen, L. G. (2011). *Modelling Transport*. Wiley.

PDFH B. (2009). *Passenger Demand Forecast Handbook*. Retrieved from unpublished

ProRail. (2014). Meer spanning op het spoor? Retrieved September 14, 2015, from https://www.prorail.nl/nieuws/meer-spanning-op-het-spoor

Provincie Groningen. (2015). Wunderline. Retrieved September 12, 2015, from http://www.provinciegroningen.nl/actueel/nieuws/nieuwsbericht/_nieuws/toon/Item/overheid-en-bedrijfsleven-steunen-verder-onderzoek-naar-wunderline/

Rienstra, S., & Groot, W. (2012). *Advies te hanteren discontovoet bij de Life Cycle Cost analyse*.

Rietveld, P. (2012). Barrier effects of borders: Implications for border-crossing infrastructures. *European Journal of Transport and Infrastructure Research*, *12*(2), 150–166.

Ross, S. (2001). *Strategische Infrastrukturplanung im Schienenverkehr* (1st ed.). Wiesbaden: Deutscher Unversitäts-Verlag DUV. http://doi.org/10.1007/978-3-322-91504-7

Schafer, A., & Victor, D. G. (2000). The future mobility of the world population. *Transportation Research Part A: Policy and Practice*, *34*(3), 171–205. http://doi.org/10.1016/S0965-8564(98)00071-8

Scheiner, J. (2010). Interrelations between travel mode choice and trip distance: trends in Germany 1976-2002. *Journal of Transport Geography*, *18*(1), 75–84. http://doi.org/10.1016/j.jtrangeo.2009.01.001

Siefer, T., & Fangrat, S. (2012). LNEE 147 - Effects of Shifting Running Time Supplements. *Proceedings of the 1st IWHIR*, *1*, 433–440.

Statistisches Bundesamt. (2006). Flugzeug oder Bahn. Retrieved from https://www.destatis.de/DE/Publikationen/STATmagazin/Verkehr/2008_02/2008_2Reiseverhalten.html

Stuttgarter Zeitung. (2012). Kritik an der Deutschen Bahn: Beim Gleisnetz ist Deutschland nur Mittelmaß - Wirtschaft - Stuttgarter Zeitung. Retrieved August 21, 2015, from http://www.stuttgarter-zeitung.de/inhalt.kritik-an-der-deutschen-bahn-beim-gleisnetz-ist-deutschland-nur-mittelmass.20eec17f-fa46-4956-ba18-0f8b48195d95.html

Unkown. (2011). Übersicht Werte der ICE-Typen. Retrieved November 1, 2015, from http://www.ice-treff.de/index.php?id=104110

Violland, M. (2011). TRAVEL / MOBILITY SURVEYS: SOME KEY FINDINGS. *International Transport Forum*, (1), 1–28.

Wardman, M. (2014). Valuing Convenience in Public Transport. *INTERNATIONAL TRANSPORT FORUM*.

Warffemius, P. (2013). *De maatschappelijke waarde van kortere en betrouwbaardere reistijden*.

Appendix A. Cross-border lines NL-DE.

Table A-1: Cross-border connections between Netherlands-Germany.

Operator	Line	From (NL)	To (DE)	Travel time [min]	Service
Arriva	20100	Groningen	Leer	1:11 → 75km	operating
Eurobahn (Keolis)	*RB 61*	*Hengelo*	*Bielefeld*	*- → 150km*	*From 2017*
Euregio-Bahn (DB)	RB 64	Enschede	Münster	1:12 → 70km	operating
Westmünsterland-Bahn	RB 51	Enschede	Dortmund	2:11 → 140km	operating
Eurobahn (Keolis)	RE 13	Venlo	Hamm	2:29 → 150km	operating
Euregio-Bahn (DB)	RE 20 (RB 33?)	Heerlen	Aachen	0:32 → 20km	operating
NS/DB	140/77	Amsterdam	Berlin	6:22	operating
NS/DB	120/78+43	Amsterdam	Frankfurt (Main)	3:55	operating

Appendix B. Expert Answers – Interview

Expert interview – Nr. 1

The participant is an anonymous person. For reasons of simplicity and a better understanding the participant will be here referred to with "He".

The experts got the following questions:

1. *Which growth do you assume for the upcoming 5 years for the rail demand between the Netherlands and Germany (ICE and ICB)? (Domestic traffic excluded)*
    a. *IC Berlin*
    b. *ICE Frankfurt*
    c. *What are the reasons for your assumption?*

A1: The participant is not familiar with the international market. For the national growth, which takes economic trends/expectations into consideration a 2% growth is expected. Overall the economic situation is considered to be stable for the coming few years. The national economic situation can be compared with the ones in the market NL-DE, therefore a 2% growth for the international market sounds not unrealistic. Due to little information a distinction between both train services cannot be made. Nevertheless, it is questionable how far the international market is comparable with the national situation.

In general also the question is raised, which factors are different for both markets (national and international). One mentioned is the fuel price effects, which might be different per country. On the other hand the effect is rather small: With an increase in fuel price, there are no tremendous shifts towards train. Second is the composition of travellers. The national market incorporates many mandatory short trips, the international market more optional long-distance trips. So in conclusion the growth of national and international are different, in cases factors change which influence only a certain group of travellers. Depending on the share of this specific traveller group (e.g. home-work) the growth on both markets is expected to be different. However, it is questionable, which factors are so exclusive that only one traveller group will be affected.

2. *The Dutch-German passenger train market is actually a border-crossing long-distance market (ICE, ICB). Assume there are no studies conducted for border-crossing behaviour for this market. Which market has then the most in common with this investigated one?*
    a. *Short-distance, border-crossing – (Grenzüberschreitender Nahverkehr) e.g. Amsterdam-Frankfurt equal to Mastricht-Aachen*
    b. *Long-distance, no border-crossing – (Fernverkehr) e.g. Amsterdam-Berlin equal to Hamburg-München*
    c. *What are the reasons for your assumption?*

A2: The NL-DE market is the most comparable with the domestic long-distance market. This is reasoned with the type of passengers travelling long-distance. Whether there is a border or not plays according to the participant no role. The border effect or cross-border penalties seems thus to be negligible, as for the IC Berlin as well as for the ICE Frankfurt the destination choice is made. Within Europe border-crossing might be for older travellers or a very small amount an issue but for the big group of travellers negligible.

3. *In line with questions 2:*
    a. *Can border-crossing penalties be neglected or not when referring to the ICB and ICE?*
    b. *If yes: Why?*
    c. *If no: How much should the penalty be and why?*

A3: See answer question 2.

4. *Literature documents elasticities for different service attributes. The most often found are:*
    - *Frequency*
    - *Fares*
    - *Travel time*

Furthermore, there is a distinction made between business passengers, commuters and different type of leisure purposes. Most of literature distinguishes between two types of travellers, namely business and non-business passengers. First incorporates all passengers travelling for any work related purpose (seldom also commuting included). The second group travels for any type of leisure (one and more day trips.

Using the three elasticity factors, which sentence holds per service attribute and why?

a. *Business passengers are MORE sensitive than non-business passengers.*
b. *Business passengers are LESS sensitive than non-business passengers.*

Elasticity	Statement	Explanation for choice
Frequency	a.	Business passengers want to spend the time only for the explicit activity. Thus, they don't want to wait but travel right after a meeting back. Same holds for the arrival, where much waiting time is not desired. However, this does not imply that the frequency needs to be high

		during the entire day. It could be that a higher frequency during peak moments is sufficient.
Fares	b.	Non-business passengers are overall the most sensitive for the cost components of a journey.
Travel Time	a.	Both passenger groups may pay attention to it. Nevertheless, the business passenger may pay more attention to this component as the non-business. The biggest interest for business travellers regarding the time component is the fact that it should be time they can use effectively. On the other hand prefer non-business passengers mainly a pleasant experience, as a leisure trip starts with the journey. However, if the leisure activity is rather limited to a short period, e.g. weekend trip, the travel time plays a bigger role.

5. *Cross-elasticities. Agree or disagree?*
    a. *ICB: If worsening a train service attribute e.g. travel time, which other modes will travellers chose instead?*
        i. *Can you give a ranking among them?*

A5a: This depends on the overall travel costs and the individual preferences. However, overall the participant assumes that many travellers will consider the airplane. This however, holds only if the fare is comparable for both modes, train and airplane. In this case, both passenger groups will consider it.

    b. *ICE: If worsening a train service attribute e.g. travel time, which other modes will travellers chose instead?*
        i. *Can you give a ranking among them?*

Both cross-elasticity statements assume ceteris paribus.
Please explain your answer.
A5b: For a shorter distance as Amsterdam-Frankfurt (compared to the IC Berlin), more passengers will opt for the car, if they have the opportunity.
Addition: Are there also other alternative modes besides car and airplane?
Yes, the bus. However, this will be not an issue for business passengers but only passengers with a small money budget and big travel time budget (e.g. younger travellers).

6. *Short- vs. long-distance elasticities. Different or not?*

On which statement do you agree or disagree and WHY?

a. *Short-distance elasticities are lower than long-distance elasticities.*
b. *Short-distance elasticities are higher than long-distance elasticities.*
c. *Short-distance and long-distance elasticities are equal.*
d. *Nothing holds.*
e. *I don't know.*

Others: The question was reformulated by the participant as follows: Do passengers react in the same way on a 10% change of short trips than a 10% change of a long-distance trip? If it is the same, the same elasticities can be used, if not others are required.
A6: Whether the elasticities are similar or different might depend on trip frequency. Travellers who are familiar with the journey know about the changes and might consider another mode. Occasional travellers might be less aware of the change. Thus answer c. for occasional travellers seems plausible. High frequent travellers may look for alternatives. They might be more sensitive on short trips, as the car might be available as alternative. On the other hand, for long-distance trips the airplane might be available. Whether the modal shift changes, depends in particular on the available alternatives. Overall, summarizing the effects together, one could assume similar elasticities.

7. *From various studies the following elasticities are drawn together (see table). We distinguish between the business and non-business passengers.*

From MNL resulting elasticities when changing rail service attributes.						
Rail service attributes	Train		Air		Car	
	Business	Non-Business	Business	Non-Business	Business	Non-Business
Travel Time						
in vehicle	1 -1	2 -0.3	3 0.9	4 0.6	5 0.4	6 0.2
Fares	7 -0.6	8 -0.9	9 0.3	10 0.1	11 0.5	12 0.3
Frequency	13	14	15	16	17	18

	0.4	0.15	-0.2	-0.4	-0.1	-0.1

Others:
The national model established by the participant uses about 10 different service attributes, which result in different aggregated elasticities. These are further distinguished by five trip purposes. Overall there evolve less than 50 elasticities. Some service attributes are not relevant for some trip purposes and are thus left out. In total there are therefore less than 50 elasticities.

Expert interview – Nr. 2

The participant is an anonymous person. For reasons of simplicity and a better understanding the participant will be here referred to with "He".

The experts got the following questions:

1. *Which growth do you assume for the upcoming 5 years for the rail demand between the Netherlands and Germany (ICE and ICB)? (Domestic traffic excluded)*
    a. *IC Berlin*
    b. *ICE Frankfurt*
    c. *What are the reasons for your assumption?*

A1: For the international market some growth in the national model is incorporated. However, this is not done by the operator but external firms. From this investigations an annual growth of about 2% is assumed for international traffic. The participant could imagine that the growth differs per line. As the IC Berlin is a rather slow product, there might be more room for improvements than for the ICE. In this sense the growth could be assumed to be higher compared to the ICE. Furthermore, the destination Berlin as a leisure city seems to have a higher attraction potential than Frankfurt. Due to too less insight in the international market, an annual growth of 2% for both lines seems plausible. The growth rate cannot be derived from the national model, as it differs in terms of available modes.

2. *The Dutch-German passenger train market is actually a border-crossing long-distance market (ICE, ICB). Assume there are no studies conducted for border-crossing behaviour for this market. Which market has then the most in common with this investigated one?*
    a. *Short-distance, border-crossing – (Grenzüberschreitender Nahverkehr) e.g. Amsterdam-Frankfurt equal to Mastricht-Aachen*
    b. *Long-distance, no border-crossing – (Fernverkehr) e.g. Amsterdam-Berlin equal to Hamburg-München*
    c. *What are the reasons for your assumption?*

A2: The IC Berlin has two functions, the international service but also the national service. Especially due to its integrated character, many national travellers make use of it. This hold less for the ICE but plays also a role for some of the domestic travellers. So in conclusion both markets (short but border, long but no border) are incorporated in the services between the Netherlands and Germany. However, the participant assumes that the main function of the lines is the long-distance service. For this reason he would compare it the most with answer b.

3. *In line with questions 2:*
    a. *Can border-crossing penalties be neglected or not when referring to the ICB and ICE?*
    b. *If yes: Why?*
    c. *If no: How much should the penalty be and why?*

A3: The cross-border penalty seems to be more important for short distance cross-border trips. This is partly reasoned by the fact that short trip purposes are mostly also available within the national borders. Therefore the participant would assume that short distance trips are preferred within the national border above cross-border trips. However, he cannot really reason this intension.

For the international trips the cross-border penalty can be neglected. The participant assumes that a trip to Maastricht would be as frequent made by train, as a trip to Germany as long as the long-distance is similar in absolute terms.

4. *Literature documents elasticities for different service attributes. The most often found are:*
    - *Frequency*
    - *Fares*

- *Travel time*

Furthermore, there is a distinction made between business passengers, commuters and different type of leisure purposes. Most of literature distinguishes between two types of travellers, namely business and non-business passengers. First incorporates all passengers travelling for any work related purpose (seldom also commuting included). The second group travels for any type of leisure (one and more day trips.

Using the three elasticity factors, which sentence holds per service attribute and why?

a. *Business passengers are MORE sensitive than non-business passengers.*
b. *Business passengers are LESS sensitive than non-business passengers.*

Elasticity	**Statement**	**Explanation for choice**
Frequency	a.	Business passengers are more sensitive for time related attributes. Reasons are the amount of available to time, which is limited. Money in contrast plays a subordinated role.
Fares	b.	In contrast non-business passengers are more sensitive to cost related attributes. Reasons for this are the budgets. Whereas the travel time budget is rather high, the financial means are limited. The latter is mainly related to the trip purpose. If one for instance considers leisure travellers, they travel for leisure. If one destination is too expensive, they might for instance choose a cheaper destination. Same holds for mode choice considerations.
Travel Time	a.	See answer frequency.

5. *Cross-elasticities. Agree or disagree?*
   a. *ICB: If worsening a train service attribute e.g. travel time, which other modes will travellers chose instead?*
      i. ***Can you give a ranking among them?***

A5a: The alternative modes are airplane, car and maybe long-distance bus services. However, the participant is not completely aware of the long-distance bus service characteristics. Nevertheless, he distinguishes between the travel and cost components. If the travel time for train increases, the modal shift towards busses will be negligible. This might be different if changing the costs attributes. A higher train fare will be in a certain moment too high, for some travellers. In this case they might be more willing to choose the bus although the travel times are rather high.

Ranking: Car, bus, airplane. Or even not to go to Berlin at all.

   b. *ICE: If worsening a train service attribute e.g. travel time, which other modes will travellers chose instead?*
      i. ***Can you give a ranking among them?***

Both cross-elasticity statements assume ceteris paribus.

Please explain your answer.

A5b: The participant assumes for the ICE a different situation, as the composition of travellers (trip purposes) is different. For instance more business passengers use this line. Thus the bus service will be not attractive. In case the train service gets worse, more people should opt for the car. He assumes that car is the most attractive. Only a small percentage will choose the plane. From all passenger leaving the train he assumes a distribution of 80% car and 20% air.

6. *Short- vs. long-distance elasticities. Different or not?*

On which statement do you agree or disagree and WHY?

a. *Short-distance elasticities are lower than long-distance elasticities.*
b. *Short-distance elasticities are higher than long-distance elasticities.*
c. *Short-distance and long-distance elasticities are equal.*
d. *Nothing holds.*
e. *I don't know.*

A6: Assuming that the trip purpose mix is equal for both, short distance and long-distance trips, the competition of alternatives plays a role. As for long-distance trips also airplanes play a role, the participant assumes higher elasticities for long-distance trips than for short distance trips. Furthermore, a travel time elasticity will have a higher impact on long-distance trips than on short distance trips. This is another reason why the elasticity for long-distances should be higher than for short distances.

7. *From various studies the following elasticities are drawn together (see table). We distinguish between the business and non-business passengers.*

From MNL resulting elasticities when changing rail service attributes.						
Rail service attributes	Train		Air		Car	
	Business	Non-Business	Business	Non-Business	Business	Non-Business
Travel Time						
in vehicle	1 -0.6	2 -0.3	3	4	5 0.4 (?)	6
Fares	7 -0.3	8 -0.9	9	10	11	12
Frequency	13 0.4	14 0.1	15	16	17	18

Cross-elasticity:

A7: 3-6

The elasticities are derived by the participant with assumed mode shares. He describes them for the time related factors travel time and frequency equal. For the alternatives bus/air/car the distribution of passengers should be 0/20/80.

A7: 9-12

Similar to the previous answer, the participant splits the diverting demand according to the mode shares for bus/air/car, which are assumed by him with 40/10/50.

A7: 15-18

See answer A7: 3-6.

<u>Expert interview – Nr. 3</u>

The participant is an anonymous person. For reasons of simplicity and a better understanding the participant will be here referred to with "He".

The experts got the following questions:

1. Which growth do you assume for the upcoming 5 years for the rail demand between the Netherlands and Germany (ICE and ICB)? (Domestic traffic excluded)
    a. IC Berlin
    b. ICE Frankfurt
    c. What are the reasons for your assumption?

A1: In national model for longer distance train trips a demand growth of 0.5% is considered. This is based on an expected population decline. Especially on landside and in economic weak regions a reduction is expected, whereas in economic strong regions, agglomerations and cities an increase in population is expected. For this reason the participant assumes for the NL-DE market a slightly higher annual growth than used in the national model. In conclusion an increase between 0.5% and 1% is advised by the participant.

Others:

There are also European studies about the TENT project for the corridor Rhine-Alpine, which investigate the connection from Rotterdam to Germany and further to Genoa. However, this might be more relevant for Freight transport.

There are national plan to increase the domestic long-distance service. This involves the combination of long and short distance services and tariffs. Furthermore, higher frequencies shall be offered and more intercity connections. This however, does not incorporate international services. Hence, this business strategy does not indicate whether the annual growth is expected to increase or not. On the other hand, the strategy implies a tactic about the new rolling stock. As service shall be combined (long and short distances) and the strategy shall be flexible, also the rolling stock planning desires flexible usage.

The newest development for the international market are the long-distance busses. In order to compete with them, the company runs an own service on dedicated routes.

2. The Dutch-German passenger train market is actually a border-crossing long-distance market (ICE, ICB). Assume there are no studies conducted for border-crossing behaviour for this market. Which market has then the most in common with this investigated one?
    a. Short-distance, border-crossing – (Grenzüberschreitender Nahverkehr) e.g. Amsterdam-Frankfurt equal to Mastricht-Aachen
    b. Long-distance, no border-crossing – (Fernverkehr) e.g. Amsterdam-Berlin equal to Hamburg-München
    c. What are the reasons for your assumption?

A 2: Answer b. The participant assumes that the majority of international passengers (passenger travelling over the border), use the end stations Amsterdam and Berlin as access or egress station. In this sense they are long-distance travellers and thus the connections are more comparable with the domestic long-distance market. Furthermore, he assumes that the international market does not differ from the national market much, as with the European Union (same currency, no border control) and the Schengen Agreement borders are less and less perceived as something negative. Available market studies do not cover enough participants of the NL-DE market in order to provide a statistically relevant insight. Nevertheless, in his opinion the national and international long-distance market are similar.

Other:

The ticket purchase is possible in both countries for the entire journey, which eases the train use for international trips.

The Netherlands is a strong country in absolute numbers of international passengers. Although the country is rather small, the same amount of passengers are carried on international lines than France. In this sense the cross-border penalties can be neglected.

3. In line with questions 2:
    a. Can border-crossing penalties be neglected or not when referring to the ICB and ICE?
    b. If yes: Why?
    c. If no: How much should the penalty be and why?

A 3: See answer A2.

4. Literature documents elasticities for different service attributes. The most often found are:
   - Frequency
   - Fares
   - Travel time

   Furthermore, there is a distinction made between business passengers, commuters and different type of leisure purposes. Most of literature distinguishes between two types of travellers, namely business and non-business passengers. First incorporates all passengers travelling for any work related purpose (seldom also commuting included). The second group travels for any type of leisure (one and more day trips.

   Using the three elasticity factors, which sentence holds per service attribute and why?

   a. Business passengers are MORE sensitive than non-business passengers.
   b. Business passengers are LESS sensitive than non-business passengers.

Elasticity	Statement	Explanation for choice
Frequency	a.	Business passengers are more interested in travelling just in time. This implies both, departure and arrival. This is clearly different from leisure passengers, who are more flexible in their moments of departure and arrival. If there is only one direct train connection per day, the latter passenger groups opts for this travel choice in contrast to the business passengers, who want to travel right on time or after an appointment. For leisure passengers this might incline with their trip frequency.
Fares	b.	Leisure passengers. However, the difference between both traveller groups is not as much as indicated by the values in the table below.
Travel Time	a.	See answer "frequency". Again the values the participant knows, do not differ as much as the values indicated in the table below.

Trip purposes the participant usually distinguishes:

Business, commuters, leisure one day, leisure trip multiple days. However, for the considered market commuters can be neglected and also leisure one day trips are rather low.

5. *Cross-elasticities. Agree or disagree?*
   a. *ICE: If worsening a train service attribute e.g. travel time, which other modes will travellers chose instead?*
      i. ***Can you give a ranking among them?***

A5a: The car displays the highest competition with the train.

   b. *ICB: If worsening a train service attribute e.g. travel time, which other modes will travellers chose instead?*
      i. ***Can you give a ranking among them?***

Both cross-elasticity statements assume ceteris paribus.

Please explain your answer.

A5b: With an increasing distance the competition to air increases. Comparing both services with each other, the ICE carries more business passengers who are more likely to travel by air, whereas Berlin carries more passengers willing to travel cheap.

Other:

For distances above 100 km, the car has a market share of about 80%. The amount of passengers who switch from a competing mode to the train (in case the train service improves), is proportional to the market shares (due to the application of MNL). This relation among modes, was also calculated with other, more advanced models. It appeared however, that the MNL represents this effect sufficiently good.

6. *Short- vs. long-distance elasticities. Different or not?*

On which statement do you agree or disagree and WHY?

a. *Short-distance elasticities are lower than long-distance elasticities.*
b. *Short-distance elasticities are higher than long-distance elasticities.*
c. *Short-distance and long-distance elasticities are equal.*
d. *Nothing holds.*
e. *I don't know.*

A6: The participant works with distances from 50 km and more. Thus, he does not know elasticities for lower distances. Furthermore the travel time elasticity increases with the distance. For distances of 100 km, the elasticity would be around -1, whereas for distance of 600 km the elasticity is somewhere at -2. For fare elasticities holds an increasing trend with increasing distance, too. However, this is not as strong as the travel time elasticity. So for an increase of 10% in travel time, decreases the demand by 10%. For fare changes the effect is less.

The participant states for frequency elasticity a similar effect. Short distance trips are offered more often, long-distance trips less, due to differences in demand totals. However, doubling the frequency of a short distance trip from 2/h to 4/h, would have most likely the same effect than doubling a long-distance trip from 0.5/h to 1/h. So overall answer a. holds for time and fare elasticities. For frequency elasticity the same effect for both distances are assumed.

7. *From various studies the following elasticities are drawn together (see table). We distinguish between the business and non-business passengers.*

From MNL resulting elasticities when changing rail service attributes.						
Rail service attributes	Train		Air		Car	
	Business	Non-Business	Business	Non-Business	Business	Non-Business
Travel Time						
in vehicle	1 -1.2 (or slightly above/ below = +/-)	2 -0.6 (+)	3	4	5	6
Fares	7 -0.6 (+/-)	8 -0.85 (+/-)	9	10	11	12
Frequency	13 +0.3 (+/-)	14 +0.15 (+/-)	15	16	17	18

Cross-elasticity:
A 7: 1
In der Mitte Ihres Intervalls. → -0.6 -1.8
A 7: 2
Geringer als Business, aber noch in dem Business-Intervall, also deutlich oberhalb Ihres Intervalls für Non-Business. → -0.2 -0.4
A 7: 7
Am unteren Rand des Intervalls. → -0.6 -2.0

A 7: 8
In der Mitte des Intervalls. → -0.6 -1.1
A7: 13
Am unteren Rand des Intervalls. → +0.3 +0.6
A 7: 14
In der Mitte des Intervalls. → +0.1 +0.2
A 7: 3-6, A 7: 9-12, A 7: 15-18:
Bei den Kreuzelastizitäten sind ja zwei Arten zu unterscheiden:
1. der Einfluss einer Angebotsänderung eines anderen Verkehrsmittels auf die Bahn
2. der Einfluss einer Bahn-Angebotsänderung auf ein anderes Verkehrsmittel

Im Vergleich zur Elastizität sind die Kreuzelastizitäten 1. Art umso größer, je größer der Marktanteil des anderen Verkehrsmittels im Vergleich zur Bahn ist, die Kreuzelastizitäten 2. Art hingegen sind umso kleiner.

Expert interview – Nr. 4

The participant is an anonymous person. For reasons of simplicity and a better understanding the participant will be here referred to with "He".
The experts got the following questions:

8. *Which growth do you assume for the upcoming 5 years for the rail demand between the Netherlands and Germany (ICE and ICB)? (Domestic traffic excluded)*
    a. *IC Berlin*
    b. *ICE Frankfurt*
    c. *What are the reasons for your assumption?*

A1: Moderate growth. Less than 1 % per year, if current service remains unchanged. He doesn't know the market well.

9. *The Dutch-German passenger train market is actually a border-crossing long-distance market (ICE, ICB). Assume there are no studies conducted for border-crossing behaviour for this market. Which market has then the most in common with this investigated one?*
    a. *Short-distance, border-crossing – (Grenzüberschreitender Nahverkehr) e.g. Amsterdam-Frankfurt equal to Mastricht-Aachen*
    b. *Long-distance, no border-crossing – (Fernverkehr) e.g. Amsterdam-Berlin equal to Hamburg-München*
    c. *What are the reasons for your assumption?*

A2: The market is the most comparable to b, since the market is more specified by its distance than by the existence of a border.

10. *In line with questions 2:*
    a. *Can border-crossing penalties be neglected or not when referring to the ICB and ICE?*
    b. *If yes: Why?*
    c. *If no: How much should the penalty be and why?*

A3: If travelling long-distance and over the border he would include a cross-border penalty. It should be then included in the penalty-function. In this way the perceived ticket price increases. The exact amount of such a penalty is difficult to determine, as they depend on the pricing strategy. For instance the government might enhance domestic train trips by subsidising them (special offer tickets). Therefore, the pricing for both, domestic tickets in NL or DE as well as international ticket pricing differences need to be known. Participant assumes that there are differences. However, the cross-border penalty won't be the decisive parameter within the mode choice. This depends more on the attractiveness of the train, compared to available alternatives rather than on the cross-border penalty. Therefore, the meaning of the penalty should not be overestimated.

11. *Literature documents elasticities for different service attributes. The most often found are:*
    - *Frequency*
    - *Fares*
    - *Travel time*

Furthermore, there is a distinction made between business passengers, commuters and different type of leisure purposes. Most of literature distinguishes between two types of travellers, namely business and non-business passengers. First incorporates all passengers travelling for any work related purpose (seldom also commuting included). The second group travels for any type of leisure (one and more day trips.

Using the three elasticity factors, which sentence holds per service attribute and why?

a. Business passengers are MORE sensitive than non-business passengers.

b. *Business passengers are LESS sensitive than non-business passengers.*

Elasticity	Statement	Explanation for choice
Frequency	a) Or b)	a) See below.
Fares	a) Or b)	b) Related to the rather long-distances, non-business passengers appear to be more flexible to time and time related attributes, than business passengers. However, they are rather sensitive to price and cost related attributes.
Travel Time	a) Or b)	a) See above.

Remark participant: The participant asks why the transfer elasticity is missing.

We: The transfers are not included due to too less sources in literature on one hand and the fact that currently a direct connection between Amsterdam and Berlin exists.

12. Cross-elasticities. Agree or disagree?
    a. ICE: If worsening a train service attribute e.g. travel time, which other modes will travellers chose instead?
        i. Can you give a ranking among them?

A5a: For a distance of about 350 km, the car plays an important role. Also the long-distance bus services might be here of interest. However, as the ICE is a high-speed train, the participant assumes that the train alternative has a significant market share, as it offers attractive travel times with a high-speed connection. More attractive than the ICB for instance. The participant would even assume the ICE service to have the highest market-share of all modes, as the decisive factor "Travel time" is rather short for the train on this OD (Amsterdam-Frankfurt). A ranking of the mode choices cannot be given, as the mode choice also depend strongly on the trip purpose.

b. ICB: If worsening a train service attribute e.g. travel time, which other modes will travellers chose instead?

i. Can you give a ranking among them?

Both cross-elasticity statements assume ceteris paribus.

Please explain your answer.

A5b: The highest competition with the IC Berlin service is assumed by the participant to be by air, as the distance of about 650 km is a distance, which is preferred by passengers to be done by train or airplane. A ranking of alternatives would result in airplane, car and long-distance busses.

13. Short- vs. long-distance elasticities. Different or not?

On which statement do you agree or disagree and WHY?

a. Short-distance elasticities are lower than long-distance elasticities.
b. Short-distance elasticities are higher than long-distance elasticities.
c. Short-distance and long-distance elasticities are equal.
d. Nothing holds.
e. I don't know.

A: As elasticities describe the percentage change in demand, given a percentage change in service, the effect on long-distance OD's is higher. For instance, given a 10 percent decrease in travel time of a short trip of 20 minutes will have a smaller impact on demand, than a 10 percent decrease of a trip with 6 hours. Whereas the first changes by 2 minutes only, the long-distance trip has a travel time gain of 36 minutes. The latter will have thus a higher impact on travel demand than the change of the first mentioned travel time. Thus, the short-distance travel times will be lower compared to the long-distance travel times, answer a.

14. From various studies the following elasticities are drawn together (see table). We distinguish between the business and non-business passengers.

From MNL resulting elasticities when changing rail service attributes.

Rail service attributes	Train		Air		Car	
	Business	Non-Business	Business	Non-Business	Business	Non-Business
Travel Time						
in vehicle	1 > -1	2 << -1	3	4	5 ~-0.4 (20% train)	6 As A5
Fares	7 <-0.4	8 <-1	9	10	11 Smaller A5	12 Smaller A6
Frequency	13 <0.4	14 Smaller A13	15	16	17	18

A 7: 1
>-1 Difficult to judge, as the participant does not know the market exactly. Nevertheless, with -1 the travel time elasticity is rather conservative. It could be also higher.
A 7: 2
<-1 The travel time elasticity depends highly on the distance travelled. As the participant is not familiar with the market, only an approximation for both travel groups, business and non-business can be given.
In general it is very important to consider the current market situation. Cross-elasticities dependent on the demand volumes of the train mode. In order to determine (cross-) elasticities it is important to understand the full market.
As the participant leaks extensive insight into the market, he recommends to use a combination of elasticities and mode choice models to determine the resulting demand per mode. The use of wrong elasticities will has a significant impact on the absolute values.
A 7: 7
-0.6 is already rather high. Therefore, a lower value of about -0.4 or smaller.
A 7: 8
Also for non-business passenger the absolute values for price elasticities are assumed to be smaller than -1. They are therefore indicated with <-1.
A7: 13
With big changes elasticities can be applied additive or multiplicative. In general the participants assumes with double frequency an increase of demand of about one third for the entire day. Depend on the calculation, the elasticity results in similar values as indicated ((60/30)^*0.4* for the multiplicative way). However, this increase is more applicable for shorter distances. For the IC Berlin connection, a duplication of the frequency will not lead to a one third increase in demand but less.
A 7: 14
In line with the distinction between business and non-business, the frequency elasticity for the latter group needs to be lower in relation to the business travellers. In case of a frequency increase within peak hours only, the elasticity of about 0.4 for business travellers needs to be adjusted. This however is rather difficult to determine in a good way.
A 7: 3-6, A 7: 9-12, A 7: 15-18:
One distinguishes between either the train attribute related changes in demand for other modes (type A), or demand changes of train, when service of competing modes changes (type B). The expert is mainly familiar with the cross-elasticity type A. For example, if the train improves by 10 %, 4% of the train demand would travel more with this modality. Without this improvement these 4% would travel with the competing modes. So in case the travel time by train gets worse (increases by 10%) and the cross-elasticity of car is +0.4, the 4% of the train traveller will travel by car. As the cross-elasticity of modality k is related to the mode shares, the service change would always lead to changes in demand, even if demand of mode k was zero before. Furthermore, using cross-elasticities for the entire network, leads even there to an increasing demand, where certain other modes are not available. For example, using a general cross-elasticity of type A, of 0.4 for the relation train, leads even then to an increasing demand, if no air service is offered on a certain OD-pair. This is thus a limitation of cross-elasticities.

A 7: 5-6

The participant is not an expert on cross-elasticities. Nevertheless, assuming a train share of 20%, a cross-elasticity of 0.4 seems plausible for car.

A 7: 11-12

For fare cross-elasticities a lower value as for the travel time cross-elasticities are plausible. Exact number however, cannot be given by the participant due to a lack of information.

Appendix C. LVM – Model steps and input

In the following, each model step is described briefly, by answering the questions *what* the model does, *how* it works and *why* this step is important. Steps which are actively modified for the international network are explained later in detail. For further information readers are referred to the Dutch paper "Optimalisatie van de lijnvoering op Railnetwerken" (Keizer et al., 2013), which was written for the CVS congress 2013.

(I) Network – Genetic algorithm

The genetic algorithm originates form evolution theory and enables the user to determine an optimal set of lines given the expected demand. In order to determine the line alignment, a predefined network is required on which the optimisation takes place. As the network consists of multiple nodes and links, constraints for the solution lines need to be set upon front, the so called candidate lines. In case certain lines are already known, or are not subject of optimisation (e.g. from other operators), they might be set as constraints to the model.

The candidate lines determine logical lines within the network and are calculated before the optimisation starts. A set of criteria is established, which serves as constraints to determine candidate lines. These are:

- Start and endpoint of a line
- Passes every station only ones
- Maximum degree of detour
- Specifications regarding Sprinter lines
- Specifications regarding Intercity lines
- Etc.

The exact values per criteria are adjustable by the user. Given these candidate lines, the algorithm saves computational time, as illogical lines are excluded beforehand. Overall the generation of lines is used as an input for the next steps.

(II) Travel options – Breath-First-Search algorithm

The determination of travel options is split into two parts, the generation of travel options per OD pair and the elimination of unnecessary options. In general a travel option is defined as the use of one or more lines with transfers between. These options differ in cycle time (e.g. every 15 min), departure time, travel time and so forth, which are calculated per iteration and population (see explanation GA Appendix D).

(a) Generate travel options

In order to generate travel options the Breath-First-Search (BFS) algorithm is applied. In a first phase, all travel options are established with zero transfers. Afterwards, the options are extended for OD pairs with one transfer. This continues until the travel options reach a maximum number of transfers. For the national setting this maximum is set to 5. However, as nearly all parameters, this can be adjusted by the user. From the Breath-First-Search algorithm multiple travel options appear per OD pair, which differ in attributes as number of transfers, travel time, etc.

(b) Remove (unnecessary) travel options

Multiple options between two nodes are in many cases not necessary regarding the available demand. Furthermore, some travel options will perform so low that they will not be considered as travel options in reality. For this reason unnecessary options are deleted and not used further to generate new travel options. In contrast to options which appear to perform good. For instance a good performing travel option with one transfer, will be used in the next step of the BFS algorithm to determine travel options with two transfers. However, if the travel option with one transfer is deleted, it cannot be part of a new travel option anymore. In order to evaluate each travel option, the number of transfers, distance, travel time as well as fares are calculated. Based on different criteria (see Appendix H), the travel options performing the lowest are eliminated. In general the options are first evaluated based on the number of transfers, then on the number of travel time and eventually on the fare. The systematic elimination of unnecessary travel options, leads to a minimum number of options which connect all nodes. The approach involves the dilemma between direct connection but long travel times versus transfer connection but lower travel times.

(III) Demand – Elasticity Model

Given the new travel options, the change in demand compared to the previous iteration needs to be determined. This is done using the elasticity model. Attributes as waiting time, travel time, and transfers are translated into a generalised journey time (GJT). Using a GJT elasticity of 0.8 reveals in the final demand for the generated line alignment. This trip generation displays the input for the next steps as it indicates both, the cost necessary to transport all demand and the revenue, the new demand will generate. A more extensive description of this step is given in sub section … .

(IV) Assignment – Utility and Multinomial logit

In the fourth step, the new demand is assigned to the network. As for most of the OD pairs different travel options exists, the different routes need to be evaluated, to make route choice possible. For this reason a utility function is used. Based on the utility and weight per travel option the MNL is applied. It is highlighted that the here presented utility function uses positive coefficients for utility factors, as VOT or attractiveness of an option, and negative coefficient for disutility factors as transfer, travel time, etc.

(a) Evaluation of travel options - utility

In order to calculate the utility (U) of a travel option i, the attractiveness per option is determined. The attractiveness is distinguished in departure and arrival attractiveness and can be decisive when choosing a line. For the departure attractiveness (DA) the attraction increases the more time passed between the departure of this and a previous travel option. On the other hand, the attractiveness of arrival (AA) increases the later the arrival time of the next travel option appears. For example, if a travel option departs at .02 and .07 and again at .22 (.42) and .27 (.47), the travel options with .02 and .22 (.42) will have in average more passengers than the .07 and .27. This is mainly based on the assumption that people arrive evenly spread at the station. Within a waiting time of 7.5 minutes (15/2) in average, more people arrive than within a waiting time of 2.5 minutes (5/2). Similar holds for AA. As people tend to be on time at a certain location, more people will opt for the earlier arriving train, the bigger the difference between the arrival times is.

As the LVM uses no timetable information, the attractiveness is calculated based on travel time per option, the supply, demand and use of a certain line of a considered travel option. However, as this rather complex procedure does not contribute to a better understanding, the exact explanation is excluded from this report.

The used utility function is the same as the one used for TRANS[12]. It incorporates travel time, transfer and fare attributes as well as the two attraction factors.

$$U_i = c_t * t_i + c_o * o_i + c_{ot} * \frac{o_{ti}}{c_d} + c_p * \frac{p_+}{\frac{VOT}{60}} + DA + AA$$

Eq. 5.3.2-1

With:

Ui	= utility of alternative i
c	= utility or disutility coefficient
ti	= in-vehicle travel time for i
oi	= number of transfers
ot	= transfer time
p+	= fare supplement
DA	= departure attractiveness

[12] TRANS is a model established by NS and ProRail to assign the future demand to the network. It has comparable features as the LVM model but incorporates the timetable as an additional constraint.

AA = arrival attractiveness

(b) Distribution over the network - MNL

Using the predefined utilities of each travel option, the demand needs to be distributed. However, travel options with low frequencies can be used less than travel options with high frequencies. Therefore the so called weightings (Gi) need to be introduced. A travel option which repeats every 15 minutes given a periodic time table of 60 minutes, will have a weight of 4 (60/15). Whereas a travel option departing ones per our will have a weight of one. Overall the distribution is calculated using the MNL model, which results in the shares (p) per travel option i.

$$p_i = \frac{G_i * e^{U_i}}{\sum_j G_j * e^{U_j}}$$

Eq. 5.3.2-2

Distributing the demand over the network using the shares p, results in the number of vehicles needed to operate this line alignment.

(V) Scores – Objective function

During the last step of each iteration, the scores are calculated which indicate the performance of a generated network. This is simply done by using the outcomes of iteration step (III) and (IV). With the new demand distributed over the network, the passenger kilometre are calculated, which reveal in the revenue. Furthermore, the number of rolling stock and personnel is calculated, which reveals in the cost. The final output is profit which shall be maximised. Hence, every network that generates an improved line alignment compared to the previous iteration, results in an increase in profit. For the genetic algorithm means this, that the found line alignment will be used in the next iteration, where a new set of lines within the candidate lines chosen for further reproduction processes.

$$Profit = revenue - cost$$

With:

$$Revenue = \sum (passenger * distance) * \ revenue/km$$

$$Cost = personnel + fix\ cost\ (IC + Spr) + var\ cost\ (IC + Spr)$$

The iteration stops when the stop criteria of a maximum number of iterations is reached.

Input data LVM

#	Network variables	description	Network parameter	description
1	station	stations in the network (regardless train type)	logistics	different parameters for the calculation of the realized travel time given the network and rolling stock attributes
2	end station	stations where IC trains (or other type of trains) turn around	passengers	different parameters for the calculation of passenger demand
3	station type	Here is defined which type of trains may stop at this station.	trans route	different parameters important for the route search algorithm
4	link	network between two neighbouring stations	trans passengers	different parameter important for the distribution of passengers on the routes
5	link restriction	exclusion of certain link combinations	generator	different parameters important for the candidate lines
6	line	Current service lines indicated by the sequence of stations		
7	line restrictions	lines which shall be excluded from the optimization		
8	waiting time	perceived waiting times dependent on		

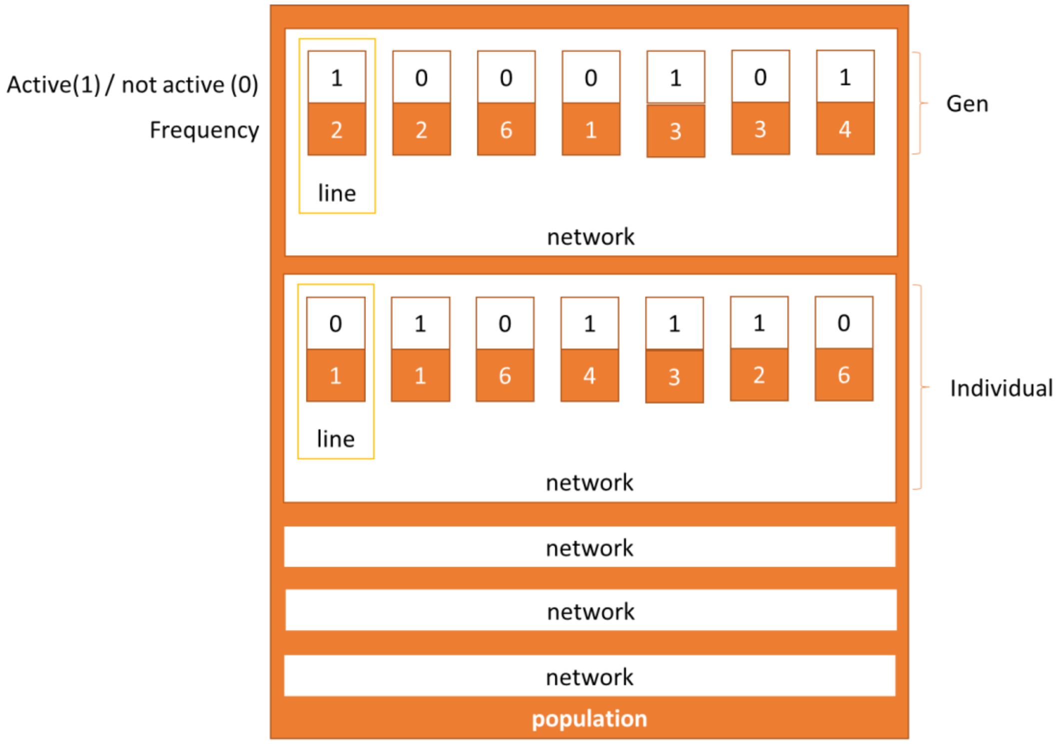
		the service frequency		
9	demand	OD matrix		

Sub objectives

Goals			Restrictions	
GJT	↓	(Decrease) generalised journey time.	Stations served	Every station need to be served.
Demand	↑	(Increase) the sum of passenger kilometres.	Links served	Every link need to be served at least as often as defined by the input data.
Number of locomotives	↓	The number of necessary locomotives.	Links occupied	Maximum amount of trains per link, dependent on the number of tracks on this link.
Number of wagons	↓	The number of necessary wagons.		
Train kilometres	↓	The sum of train kilometres.		
Travel time train	↓	The sum of train kilometres (=personnel costs).		
Number of stops	↓	The number of stops served.		
Number of transfers	↓	The average number of transfers per passenger.		
"turbulentie"	↓	The number of passengers having a travel time which is worse than the reference one.		

Appendix D. Genetic algorithm

Within a network of nodes hundreds of line combinations are possible. Determining first all possible lines and then evaluating them against each order is a time and calculation intense process. A more sophisticated method is the use of an algorithm. Based on the graduation work of Niek Guis from the TU Delft, the LVM uses the genetic algorithm to find an optimal network. As the algorithm originates from evolution theory, one usually refers to the population, individuals, genes and alleles. For the LVM these parts are translated into a set of multiple networks given the infrastructure (population), each set consists of one network (individual), which consists again of a number of lines (gen). Each line combines two attributes (allele). First, the frequency on a certain line and second, whether this line is active or not. In this section, the genetic algorithm is briefly explained. For further information we refer to (Guis et al., 2012). The following figure illustrates all parts of the algorithm.



The algorithm starts with the creation of at least one initial population. This can be extended to a number of populations depending on the user. In an iterative process the characteristics of the networks are adjusted by recomposing their lines. The exact procedure accomplishes five steps per iteration, which will be explained in the next paragraphs.

5. Determination of initial population.
6. Determination of scores per network.
7. Choice for "reproduction".
    a. *Crossover reproduction.*
    b. *Mutation reproduction.*
8. Selection of the elite.
9. Stop criteria.

Determination of initial population

As a first step, one or more populations are created. Given the nodes and links in the network, different combinations are created. These results in different networks, which are summarized to one population. These possible lines within a network are called *candidate lines*. In order to limit the number of lines and a set of criteria or constraints is stated, which limits the possibilities. These criteria are for instance the maximum or minimum length of a line, the degree of detour compared to the crow fly distance, the maximum or minimum number of main stations, the lines need to pass, etc. As a network often consists of different network levels (e.g. Sprinter vs. Intercity service), all criteria might be set separately per service. However, it is up to the user to determine the criteria desired. At all events, the constraints set upon front support the algorithm to predefine possible lines and hence save computation time. In addition to the pre-set criteria, the attributes per line are defined (gen). Hence, the initial lines with associated frequencies are defined.

Determination of scores per network

How good a network (line set) performs compared to others, is measured as a score. The more criteria are accomplished, the better the total result. However, a good score does not consequently imply, that the line set will be placed in the optimal solution and vice versa. Lines sets with bad scores can be still selected for the next step, although their probability is low. The “score” is subject to the objective function, which might be the minimisation of costs or maximisation of revenues and profit.

Choice for ”reproduction”

According to the scores each line achieved, the probability for ”reproduction” increases. Lines which are not selected for reproduction are deleted from the set of possible alternatives in the network. In this way the number of solution decreases.

Crossover reproduction

In the following step, some of the available networks are composed to pairs of two, the so called *parents*, where again each network consists of multiple lines. Within the crossover process, the parents exchange a set of lines. For example the ”mother network” exchanges line 3, 4 and 5 with the lines of the ”father line” at the same position. This leads to a new set of possible lines within the network. The modified network are then again evaluated using the scores. In some cases the crossover worsens the total result of both lines.

Mutation reproduction

The part of the networks, which are not reproduced yet, are mutated. By adjusting one attribute per line, the chances are increased to find an optimum solution within the search area. Furthermore, the mutation decreases the probability that the solution is searched within a local optimum only. This is done by either increasing or decreasing one line attribute with a maximum of one per step. For example, an active line with a frequency of 4, will be set inactive. Or another active line, which has a frequency of 2, will receive a frequency of one or three. In contrast, the latter example cannot receive a frequency of four and higher.

Selection of the elite

The lines revealing from the reproduction process as the best solutions are set into the elite group. This assures their results. For the next iteration process they are not reconsidered and can thus not be destroyed by a crossover or mutation reproduction process. Overall, they are counted as parts of the optimum network.

Stop criteria

The iteration process is in fact infinite. However, after a while, no better solution can be found. Therefore, the algorithm may consist of different stop criteria, as: Maximum number of generations, maximum time reached, maximum number of generations without further improvement.

For the LVM the first criteria is used.

Appendix E. Remove of (unnecessary) travel options

In the following the criteria are described on which unnecessary travel options are eliminated.

Definitions:

o_n = Transfer of travel option n.

tt_n = Travel time of travel option n.

c_n = Costs of travel option n.

d_n = Distance of travel option n.

TO = Travel option (= links + transfers).

to_n = Travel option attributes of option n (= transfers + travel times).

Process:

1. $o_n = o_{n+1}$; (Transfer of option n equals transfer of option n+1.)

   1.1. $tt_n = tt_{n+1}$

   1.1.1. $to_n = to_{n+1}$

   1.1.1.1. $c_n < c_{n+1}$ → $TO_n << TO_{n+1}$; (... and if costs of option n are smaller than costs of option n+1, travel option n will be chosen. Travel option n+1 can be deleted).

   1.1.1.2. $c_n > c_{n+1}$ → $TO_n >> TO_{n+1}$

   1.1.1.3. $c_n = c_{n+1}$ → $TO_n << TO_{n+1}$

   Choose the travel option, which passes the stronger station.

   (The stronger station is determined with the number of departing lines. The more lines depart, the stronger or more important a station is considered.)

   1.2. $tt_n < tt_{n+1}$ and $c_n \leq c_{n+1}$

   1.2.1. $d_{n+1} - d_n \geq$ allowed detour (5 km). → $TO_n << TO_{n+1}$

   1.2.2. $tt_{n+1} - tt_n >$ allowed travel time with equal amount of transfers (20 min). → $TO_n << TO_{n+1}$

   1.2.3. $to_n = to_{n+1}$ → $TO_n << TO_{n+1}$

   1.3. $tt_n > tt_{n+1}$ and $c_n \geq c_{n+1}$

   Similar to 1.2. but then reversed signs.

2. $o_n < o_{n+1}$

   2.1. $c_n \geq c_{n+1}$ and $tt_n - tt_{n+1} >$ allowed travel time loss ($o_{n+1} - o_n$). → $TO_{n+1} << TO_n$

   2.2. $c_n \leq c_{n+1}$

   2.2.1. $tt_n < tt_{n+1}$ and $d_{n+1} - d_n \geq$ allowed detour (5 km). → $TO_n << TO_{n+1}$

   2.2.2. $tt_n - tt_{n+1} <$ minimum travel time gain compared to direct connections for lines with transfer (10 min). → $TO_n << TO_{n+1}$

2.2.3. tt_n - tt_{n+1} < minimum travel time gain compared to direct connections for lines with transfer (10 min).

AND, the connections are not alternating[13]. → $TO_n << TO_{n+1}$

2.2.4.

3. $o_n > o_{n+1}$

Similar to 2. but then reversed signs.

[13] If the connections are alternating both travel options remain: In case TO1 leaves at .00 and .30, and TO2 leaves at .15 and .45, the travel options might be the same. But due to their long waiting times, they are both attractive and thus not eliminated from the solution area.

Appendix F. Validation data

The average trip length is calculated based on the number of passengers and their distance travelled. Due to confidentiality, the spreadsheet cannot be provided. From the calculation reveals an average trip length for international passengers (IC Berlin): 360 km. With the average trip length and the average international passengers travelling per day, the international trip kilometres are provided:

360 km * 2122 pax/ day = 763,920 pax km.

In the following table, the percentage increase in passengers is presented. The passenger numbers are extracted from the LVM output. Due to confidentiality, these numbers are deleted in the final version of this report.

As can be seen, the number of passengers between Amsterdam and a German station increase by 6 percent. Due to the used travel time elasticity of -0.6, the increase is in line with expectations. For the national passengers, the increase is lower. This is explained in the next paragraph.

From	To	Passenger_ reference	Train	passenger_ travel time decrease by 10%	Traffic	Difference %	GRT_ reference	GRT_travel time decrease by 10%	manual (GRT-el = -0.8)
Amsterdam	Ber	x	IC B	x	International	6.42%			
Amsterdam	HBTH	x	IC B	x	International	6.10%			
Amsterdam	HH	x	IC B	x	International	6.22%			
Amsterdam	HM de	x	IC B	x	International	6.14%			
Amsterdam	HO	x	IC B	x	International	6.13%			
Amsterdam	HR de	x	IC B	x	International	6.33%			
Amsterdam	HWOB	x	IC B	x	International	6.29%			
Amsterdam	LS	x	IC B	x	International	6.35%			
Amsterdam	Amf	x	IC B	x	National	1.10%	57.47	56.69	1.10%
Amsterdam	Aml	x	IC B	x	National	5.91%	142.08	132.2	5.94%
Amsterdam	Apd	x	IC B	x	National	5.05%	102.88	96.74	5.05%
Amsterdam	Dv	x	IC B	x	National	5.27%	115.26	108.1	5.26%
Amsterdam	Hgl	x	IC B	x	National	6.01%	154.3	143.46	6.00%
Amsterdam	Hvs	x	IC B	x	National	0.94%	43.38	42.87	0.95%

The national passengers are calculated based on a GJT-elasticity of 0.8. For the OD-pair Amsterdam-Amersfoort (Amf) and Amsterdam-Hilversum (Hvs), there are in total four travel options per hour. One with the IC Berlin, one with a national IC service and a sprinter service operating two times per hour. The GJT is calculated as an average of the four travel options. In consequence, the travel time decrease by 10 percent, leads to a decrease in GJT, which is an average of all travel options. Similar holds for the links Amsterdam-Hengelo (Hgl), or Deventer (Dv). Calculating the new GRT differences manually, leads thus to the same results as provided by the LVM.

In the following figure, four print screens of the LVM are provided. The travel time decease is highlighted in the circles.

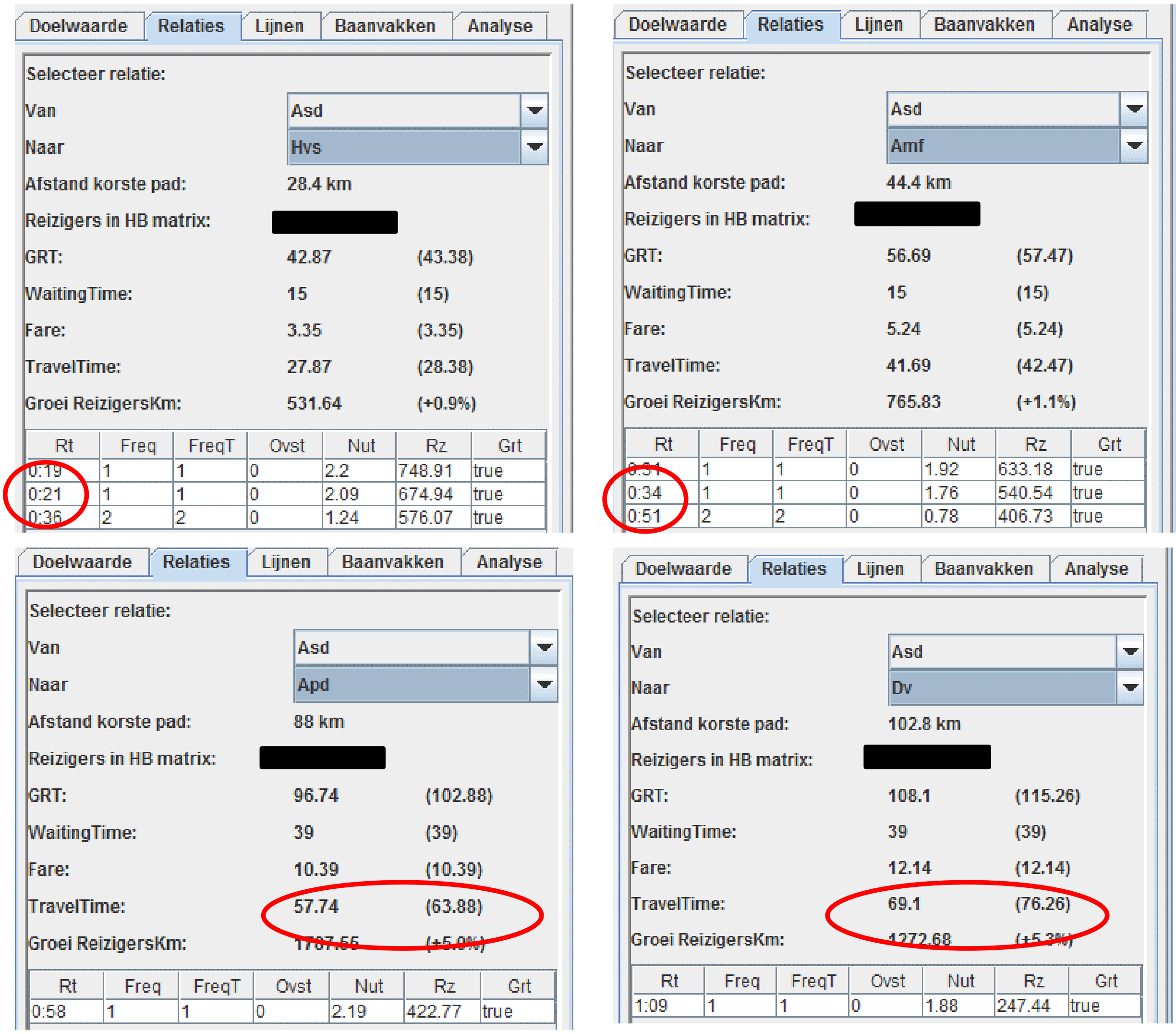


Figure F-1: National elasticity calculation.

Appendix G. Modelling alternatives – Infrastructure calculation

The infrastructure alternative is provides new and improved infrastructure. In specific, for this alternative high-speed infrastructure will be built between Amsterdam and Hannover. For the remaining section, Hannover-Berlin, the available infrastructure will be used. In order to realise high-speeds, the ICE3 series 403 is selected, since it provides interoperable technique for both systems (used for the ICE Frankfurt).

Alternatives - Travel time calculation

From an optimistic and pessimistic calculation of the travel times, the following outcomes are summarised:

- The travel time decreases from 380 min to 216 min (300km/h) → ~43%
- The maximum speed of 330 km can be mainly driven in Germany, as the distance between two successive stations is too short in the Netherlands. From the optimistic and pessimistic calculation, we decide on a calculation for of the travel time with a maximum speed of 300 km/h - "pessimistic calculation".
- In average, a running time supplement of 7% is obtained for the IC Berlin, when rounding up to full minutes.

INFRASTRUCTURE ALTERNATIVE (PESSIMISTIC calculation)

In the pessimistic scenario, the travel time calculation is based on a maximum speed of 300 km/h, and a running time supplement of 7%.

The acceleration factor is calculated as a weighted average (Table G-1). In reality, the factor varies dependent on the velocity. It is the highest, when accelerating to low speeds and diminishes with increasing speeds.

Table G-1: Acceleration factor – calculation for the ICE3.

Full Speed		300	km/h		
		83.3	m/s		
speed		acceleration factor	share	weightings	decceleration factor
v0	v1	a			a
km/h	km/h	m/s2	(v1-v0)/300	a*share	m/s2
0	100	0.71	33%	0.24	0.5
100	160	0.69	20%	0.14	0.5
160	200	0.43	13%	0.06	0.5
200	230	0.34	10%	0.03	0.5
230	250	0.3	7%	0.02	0.5
250	300	0.27	17%	0.05	0.5
Sum		2.74	100%		
Average		0.46			
Weighted average				**0.53**	

As explained, the acceleration is the highest between (v_0) = 0 km/h and (v_1) = 100 km/h. The values are retrieved from the website ICE-Treff (Unkown, 2011). Given the acceleration factors, as well as the weightings (shares), the average acceleration is calculated with 0.53 m/s^2. The deceleration factor, is derived from the values for the Thalys (CIE4811, 2008).

Based on this data, the new travel time calculation is presented Table G-2.

Table G-2: Infrastructure alternative – travel time calculation – pessimistic.

ICE	300	km/h
max speed	83.3	m/s
a acc	0.53	m/s2
a dec	0.5	m/s2

PESSIMISTIC CALCULATION

1	2	4	12	14	15	16	18	19	22	23	24	25	26	28
#	**From**	**To**	**Distance**	**Acc**	**dec**	**Full Speed**	**acc Time**	**dec Time**	**Full Speed**	**Dwell Time**	**Supplement**	**Supplement**	**Total Time**	**Final TT**
			km	km	km	km	**sec**	**sec**	**sec**	**sec**	**sec**	**sec**	sec	**hours**
				s=0.5*v2/a	s=0.5*v2/a		t=v/a	t=v/a			**5%**	**rounded**		
1	asd	hvs	**28.4**	6.6	6.9	14.9	157	167	179	120	25	60	683	**0.2**
2	hvs	amf	**16**	6.6	6.9	2.5	157	167	30	120	18	60	534	**0.1**
3	amf	apd	**43.6**	6.6	6.9	30.1	157	167	361	120	34	60	865	**0.2**
4	apd	dv	**14.8**	6.6	6.9	1.3	157	167	16	120	17	60	520	**0.1**
5	dv	aml	**38.8**	6.6	6.9	25.3	157	167	304	120	31	60	808	**0.2**
6	aml	hgl	**14.6**	6.6	6.9	1.1	157	167	13	120	17	60	517	**0.1**
7	hgl	hbth	**41.1**	6.6	6.9	27.6	157	167	331	120	33	60	835	**0.2**
8	HBTH	HR de	**21.3**	6.6	6.9	7.8	157	167	94	120	21	60	598	**0.2**
9	HR de	HO	**47.3**	6.6	6.9	33.8	157	167	406	120	36	60	910	**0.3**
10	HO	HOY	**52.7**	6.6	6.9	39.2	157	167	470	120	40	60	974	**0.3**
11	HOY	HM de	**15**	6.6	6.9	1.5	157	167	18	120	17	60	522	**0.1**
12	HM de	HH	**61.4**	6.6	6.9	47.9	157	167	575	180	45	60	1139	**0.3**
13	HH	HWOB	**74.9**	6.6	6.9	61.4	157	167	737	120	53	60	1241	**0.3**
14	HWOB	LS	**75.4**	6.6	6.9	61.9	157	167	743	120	53	60	1247	**0.3**
15	LS	Ber	**104.7**	6.6	6.9	91.2	157	167	1094	0	71	120	1538	**0.4**
	SUM		**650**			447.6	2358	2500	5371		511	960	12929	**3.6**

The current line is composed by 18 stops: 16 intermediate and 2 end stations. Bad Oeynhausen and Bünde are alternating operated. Furthermore, Berlin and Berlin-Spandau are summarised to one station, due to the low amount of passengers using Spandau. Thus, from the 16 remaining stops, 15 OD-pairs result (column 1). The distances between the OD-pairs are extracted from the LVM (column 12). The acceleration (deceleration) distances and times are equal, as the train either starts from standstill or decelerates to standstill in every section. The distance, on which full speed is possible (column 16), is obtained by subtracting the acceleration and deceleration distances (14, 15) from the section distance (12). The maximum time, full-speed running times are realised is illustrated in column 22. As can be seen, for the OD-pairs 2, 4, 6, and 11 the maximum speed is realised for less than one minute. Between Bad-Bentheim and Rheine (OD-pair row 8), the maximum speed is realised for 1.5 minutes, before the vehicle needs to start deceleration.

The dwell times (column 23) are equal to the current dwell times and are derived from the timetable information ("DB BAHN," 2015). At Hannover, the scheduled dwell time is 3 minutes. At all remaining station 2 minutes.

In the Netherlands as well as Germany, a supplement of 5% of the running time between two successive stations is used (Siefer & Fangrat, 2012), which is illustrated in column 24. However, these obtained times are rounded up to full minutes in practice, which reveals in a supplement of 960 seconds (column 25) or 7 percent.

From this calculation reveals a final travel time for the infrastructure alternative of 3.6 hours, or 216 minutes.

Without rounding up to full minutes, the calculation results in a travel time of around 210 minutes (column 25-left): 216 min – (960/60) + (511/60).

INFRASTRUCTURE ALTERNATIVE (OPTIMISTIC calculation)

In the optimistic scenario, the travel time for the infrastructure alternative is calculated with a maximum speed of 330 km/h and a running time supplement of 5%.

As illustrated in Table G-3 column 22, on the OD-pairs 2, 4, 6 and 11, the maximum speed cannot be reached due to the small distances. Between Bad Bentheim (HBTH) and Rheine (HR de), the speed is driven for less than one minute.

From the optimistic calculation reveals a final travel time of 3.4 hours or 204 minutes.

From the calculations, the following aspects are concluded:

➔ ***As on 27% of all sections (OD-pairs) the maximum speed of 330 km/h cannot be reached (column 22), the pessimistic calculation is considered to be more realistic.***

Table G-3: New travel time calculation (optimistic values)

ICE	330 km/h
max speed	91.7 m/s
a acc	0.5 m/s2
a dec	0.5 m/s2

OPTIMISTIC CALCULATION

1	2	4	12	14	15	16	18	19	22	23	24	25	27
#	**From**	**To**	**Distance**	**Acc**	**dec**	**Full Speed**	**acc Time**	**dec Time**	**Full Speed**	**Dwell Time**	**Supplement**	**Travel Time**	**Final TT**
			km	km	km	km	**sec**	**sec**	**sec**	**sec**	**sec**	sec	**hours**
				s=0.5*v2/a	s=0.5*v2/a		t=v/a	t=v/a			**5%**		
1	asd	hvs	**28.4**	8.4	8.4	11.6	183	183	126	120	25	638	**0.2**
2	hvs	amf	**16**	8.4	8.4	-0.8	183	183	-9	120	18	496	**0.1**
3	amf	apd	**43.6**	8.4	8.4	26.8	183	183	292	120	33	812	**0.2**
4	apd	dv	**14.8**	8.4	8.4	-2.0	183	183	-22	120	17	482	**0.1**
5	dv	aml	**38.8**	8.4	8.4	22.0	183	183	240	120	30	757	**0.2**
6	aml	hgl	**14.6**	8.4	8.4	-2.2	183	183	-24	120	17	480	**0.1**
7	hgl	hbth	**41.1**	8.4	8.4	24.3	183	183	265	120	32	783	**0.2**
8	HBTH	HR de	**21.3**	8.4	8.4	4.5	183	183	49	120	21	556	**0.2**
9	HR de	HO	**47.3**	8.4	8.4	30.5	183	183	333	120	35	854	**0.2**
10	HO	HOY	**52.7**	8.4	8.4	35.9	183	183	392	120	38	916	**0.3**
11	HOY	HM de	**15**	8.4	8.4	-1.8	183	183	-20	120	17	484	**0.1**
12	HM de	HH	**61.4**	8.4	8.4	44.6	183	183	486	180	43	1076	**0.3**
13	HH	HWOB	**74.9**	8.4	8.4	58.1	183	183	634	120	50	1170	**0.3**
14	HWOB	LS	**75.4**	8.4	8.4	58.6	183	183	639	120	50	1176	**0.3**
15	LS	Ber	**104.7**	8.4	8.4	87.9	183	183	959	0	66	1392	**0.4**
	SUM		**650**			397.9	2750	2750	4341		492	12073	**3.4**

Appendix H. Modelling alternatives – Rolling stock calculation

The new rolling stock shall provide maximum speeds of 230 km/h. In comparison, the old rolling stock is built for 200 km/h. However, as on the infrastructure between Amsterdam and Bad Bentheim, no higher speeds than 130 km/h are allowed, the utilisation is only possible on the German network. This however requires insight into the German timetabling, which is at this stage of the study not provided.

Thus, the rolling stock alternative focusses on the interoperable rolling stock. The travel time reduction is related to a former timetable analysis in 2014 and is presented in the following section.

ROLLING STOCK ALTERNATIVE

In the reference case (current timetable 2015), the locomotive change requires 10 minutes waiting time at Bad Bentheim. This time is saved using interoperable rolling stock. However, passing the border 10 minutes earlier requires adjustments in the timetable.

For this scenario, a travel time calculation was conducted in 2014, using DONNA[14]. The calculation is presented in Table L-1. Based on this travel time the rolling stock alternative is calculated. The calculation shows that an earlier arrival at the border, leads to a travel time reduction of 9 minutes (excluding the waiting time in Bad Bentheim). This reduction is considered as slack within the Dutch timetable (row 52). It is highlighted that in 2014 the timetable was slightly different than in 2015. The locomotive and crew change in Bad Bentheim was conducted in 8 minutes. In 2015, for the same process 10 minutes are scheduled as presented in Figure H-1 (arrival: .16, departure: .28; dwell time: 2 minutes).

Amsterdam Centraal	Di, 03.11.15	ab	13:01	2:15	0
Bad Bentheim	Di, 03.11.15	an	15:16		

Bahnhof/Haltestelle	Datum	Zeit		Gleis	Produkte
Amsterdam Centraal	Di, 03.11.15	ab	13:01	10b	IC 147
Hilversum		ab	13:22	2	
Amersfoort		ab	13:37	1	
Apeldoorn		ab	14:03	3	
Deventer		ab	14:17	1	
Almelo		ab	14:45	2	
Hengelo		ab	14:59	3	
Bad Bentheim	Di, 03.11.15	an	15:16	1	

Amsterdam Centraal	Di, 03.11.15	ab	13:01	6:14	0
Berlin Hbf (tief)	Di, 03.11.15	an	19:15		

Bahnhof/Haltestelle	Datum	Zeit		Gleis	Produk
Amsterdam Centraal	Di, 03.11.15	ab	13:01	10b	IC 147
Hilversum		ab	13:22	2	
Amersfoort		ab	13:37	1	
Apeldoorn		ab	14:03	3	
Deventer		ab	14:17	1	
Almelo		ab	14:45	2	
Hengelo		ab	14:59	3	
Bad Bentheim		ab	15:28	1	
Rheine		ab	15:42	4	
Osnabrück Hbf		ab	16:08	11	
Bünde(Westf)		ab	16:29	2	
Minden(Westf)		ab	16:49	13	
Hannover Hbf		ab	17:21	9	
Wolfsburg Hbf		ab	17:55	5	
Stendal		ab	18:27	2	
Berlin-Spandau				5	
Berlin Hbf (tief)	Di, 03.11.15	an	19:15	2	

Figure H-1: Waiting time Bad Bentheim 2015.

Although the waiting time is 2 minutes longer in 2015, the total travel time between Amsterdam and Berlin takes 6.14 hours. This is 10 minutes faster than in 2014. In Table H-1, the travel time for the same OD-pair is presented with 6.24 hours (6.35 hours until Berlin Ostbahnhof - 11 minutes). Given these differences, we calculate in the reference case with approximated time. Thus, the travel time between Amsterdam and Berlin is around of 380 minutes, or 6.20 hours and is the basis for all calculated alternatives.

The presented travel time differences and the NS calculation presented in Table H-1, give a first approximation of the available slack time. For the German timetable, DB was asked to provide a similar calculation. In a

[14] NS tool to model timetable adjustments.

meeting between NS and DB, the German operator explained that similar or even higher travel time savings are possible. However, the station Hannover, which is one of the intermediate stops of the IC Berlin, causes currently many delays. Therefore, they are not willing to provide such a calculation. Yet, there is a parallel project running regarding the delays at station Hannover. From the moment this project is finished, shorter travel times are feasible on the German timetable.

As the travel times differ per year, an exact travel time saving per minute is not appropriate. For this reason, the travel time savings are provided as an approximation, based on the insights gained at NS and the communication with DB. They are summarised as follows:

1. ~ 10 minutes travel time savings at Bad Bentheim.
2. ~ 10 minutes travel time savings in the Netherlands due to a new train path (calculated with DONNA).
3. ~ 10 minutes travel time savings in Germany due to a new train path, as reveals from conversations.

It is highlighted that this travel time calculation incorporates a high level of uncertainty. In case, DB is unable to improve the performance of Hannover station, the travel time savings are reduced to around 20 minutes. Based on the total travel time of 380 minutes (reference scenario), a travel time reduction of 30 minutes, results in a travel time savings of 8 percent. In case the maximum travel time savings are solely 20 minutes, the travel time reduction represents 5 percent of the total travel time.

The exact utilization of higher speeds is not investigated, due to the reason that the Dutch network does not support speeds above 130 km/h and 140 km/h. This might be useful on the German network. However, it requires the calculation of a new train path within the German timetable, which is at this point not feasible. For this reason, the impacts of the increased speed cannot be investigated at this point of the study.

Table H-1: Timetable calculation 2014 – interoperable scenario.

row			Heute		Ohne Lokwechsel via Amersfoort fördert 15' Verschiebung des Nationalfahrplans in den Niederländen		
			Fahrplan minuten	Reisezeit *Haltezeit*	Fahrplan minuten	Reisezeit	Delta
1	**Berlin Ostbahnhof**	V	**:25**		**:25**		
2	Berlin Hauptbahnhof Lehrter Bf	A	**:32**	0:07	**:32**	0:07	0 minuten
3	Berlin Hauptbahnhof Lehrter Bf	V	**:36**	*0:04*	**:36**	*0:04*	0 minuten
4	Berlin Spandau	A	**:50**	0:14	**:50**	0:14	0 minuten
5	Berlin Spandau	V	**:52**	*0:02*	**:52**	*0:02*	0 minuten
6	Stendal	A	**:31**	0:39	**:31**	0:39	0 minuten
7	Stendal	V	**:34**	*0:03*	**:34**	*0:03*	0 minuten
8	Wolfsburg	A	**:03**	0:29	**:03**	0:29	0 minuten
9	Wolfsburg	V	**:05**	*0:02*	**:05**	*0:02*	0 minuten
10	**Hannover Hbf**	A	**:37**	0:32	**:37**	0:32	0 minuten
11		V	**:40**	*0:03*	**:40**	*0:03*	0 minuten
12	Minden (Westf)	A	**:10**	0:30	**:10**	0:30	0 minuten
13	Minden (Westf)	V	**:12**	*0:02*	**:12**	*0:02*	0 minuten
14	Bad Oeynhausen	A					
15	Bad Oeynhausen	V					
16	Bünde (Westf)	A	**:30**	0:18	**:30**	0:18	0 minuten
17	Bünde (Westf)	V	**:32**	*0:02*	**:32**	*0:02*	0 minuten
18	**Osnabrück Hbf**	A	**:51**	0:19	**:51**	0:19	0 minuten
19		V	**:53**	*0:02*	**:53**	*0:02*	0 minuten
20	Rheine	A	**:19**	0:26	**:19**	0:26	0 minuten
21	Rheine	V	**:21**	*0:02*	**:21**	*0:02*	0 minuten
22	Bad Bentheim	A	**:34**	0:13	**:34**	0:13	0 minuten
23		V	**:44**	*0:10*	**:36**	*0:02*	**-8 minuten**
24	*Bad Bentheim/Oldenzaal grens*	*D*	**:49**	0:05	**:41**	0:05	0 minuten
25	**Hengelo**	A	**:01**	0:12	**:53**	0:12	0 minuten
26		V	**:02**	*0:01*	**:55**	*0:02*	1 minuten
27	Almelo	A	**:14**	0:12	**:05**	0:10	-2 minuten
28		V	**:16**	*0:02*	**:06**	*0:01*	-1 minuten
29	Deventer	A	**:42**	0:26	**:29**	0:23	-3 minuten
30		V	**:48**	*0:06*	**:32**	*0:03*	-3 minuten
31	Apeldoorn	A	**:59**	0:11	**:43**	0:11	0 minuten
32		V	**:00**	*0:01*	**:46**	*0:03*	2 minuten
33	**Amersfoort**	A	**:24**	0:24	**:10**	0:24	0 minuten
34		V	**:26**	*0:02*	**:12**	*0:02*	0 minuten
35	Hilversum	A	**:38**	0:12	**:23**	0:11	-1 minuten
36		V	**:39**	*0:01*	**:24**	*0:01*	0 minuten
37	Zwolle	A					
38		V					
39	Lelystad	A					
40		V					
41	Almere Centrum	A					
42		V					
43	**Amsterdam Centraal**	A	**:00**	0:21	**:43**	0:19	-2 minuten
44	Duivendrecht	A					
45		V					
46	Amsterdam Zuid	A					
47		V					
48	**Schiphol**	A					
49							
50	Reisezeit Berlin-Amsterdam		**6:35**		**6:18**		
51					Berlin-Amsterdam Centraal		
52	Savings on the Dutch side		0		**-9 minuten**		
54	Mehrspannungslok benötigt				Ja		
56	15' Drehung NL-Fahrplan erförtdert				Ja		
58	Integration in IC möglich				Deventer-Amsterdam		
60	Amsterdam direkt				Ja		

Appendix I. Modelling alternatives – Revenue calculation

REVENUE ALTERNATIVE

For the reference case, a ticket price of 65 euros is used. For a return trip to Berlin passengers would pay 130 euros. In order to make the train more attractive, the price is lowered by 15 euros. The ticket price is then 50 euros for a single trip and is thus cheaper than the car. The train is then the cheapest mode after the bus.

As illustrated in Figure L-1, prices for the modes airplane, car, long-distance bus and train are compared. The prices are provided for the OD-pair Amsterdam-Berlin, and are comparable in the opposite directions. There is a distinction made between departing on Wednesday (weekday) and Friday (weekend day). For the modes air and train, a dynamic revenue management is observed. This means prices increase, the closer the moment of departure, and prices are higher, where demand is high. In case of the connection Amsterdam-Berlin, the demand is the highest on the Friday and Sunday, as these are the days, leisure passengers travel for their short trip. For the remaining modes car and long-distance bus, the prices are constant.

In Table L-1, the mean value over all booking weeks (week 1,4,8) is provided. Rounding this value, reveals in an average price for train tickets of 55 euros during the week (Wednesday) and 65 euros on a weekend (Friday). For further calculations, the average ticket price of 65 euros is considered.

However, it is highlighted that this is actually an overestimation. As the demand matrix is based on an average day, the fare price should be an average between week and weekend day. Nevertheless, equal to the infrastructure calculation a more conservative (pessimistic) approach is preferred.

Figure I-1: Price comparison between air, car, bus and train (10.09.2015)

Sources:

Car: http://de.statista.com

Airplane: https://www.cheaptickets.nl

Fernbus: http://meinfernbus.de

Train: db.de

Table I-1: Price comparison between air, car, bus and train (10.09.2015)

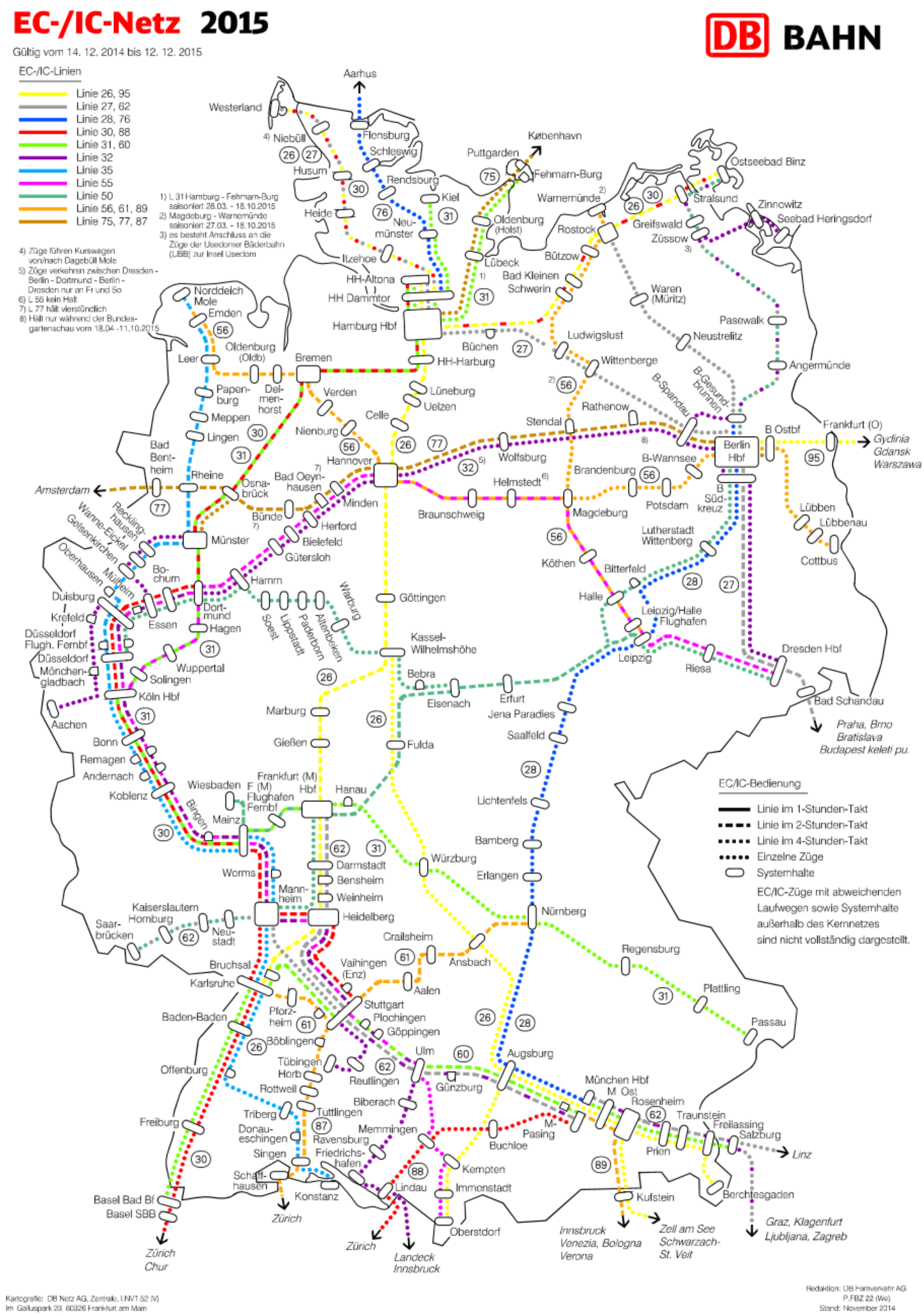
Asd-Ber						Refernece date:		10.09.2015
1	2	3	4	5	6	7	8	9
	Wednesday	Wednesday	Wednesday	Wednesday	Friday	Friday	Friday	Friday
week*	air (wed)	car (wed)	bus (wed)	TRAIN (wed)	air (fri)	car (fri)	bus (fri)	TRAIN (fri)
1	€ 57	€ 59	€ 29	€ 67	€ 80	€ 59	€ 29	€ 76
4	€ 58	€ 59	€ 29	€ 59	€ 58	€ 59	€ 29	€ 66
8	€ 27	€ 59	€ 29	€ 46	€ 75	€ 59	€ 29	€ 47
Mean**	€ 48	€ 59	€ 29	€ 57	€ 71	€ 59	€ 29	€ 63
rounded	€ 45	€ 60	€ 30	€ 55	€ 70	€ 60	€ 30	€ 65
*	booking in advance -> e.g.: week 1 = booking the tickets one week in advance							
**	average of week 1 to 12							

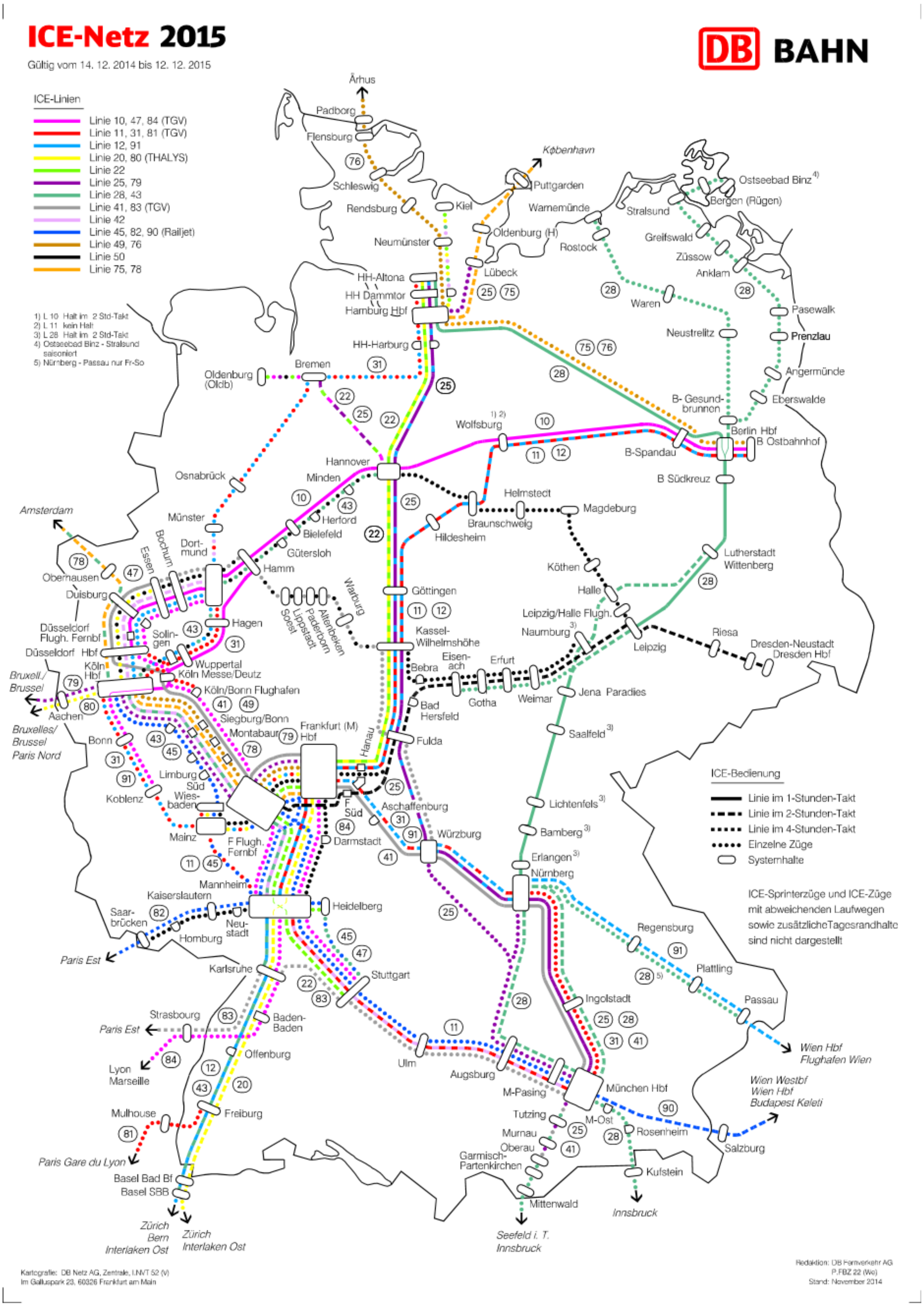
Appendix J. Modelling alternatives

The table shows some optimisation runs on different computers (acer, mac, etc.). One optimisation takes approximately 10 hours. The here presented train demand per day is not correct (overestimated), since the used input file was wrong. However, the optimisation runs from the 09.08.2015 show the deviation, when using a genetic algorithm. As can be seen, the outcomes are up to 3% over or underestimated. However, from this testing it is assumed that two or three optimisations for later situations are preciese enough, to be compared with the presented alternatives from chapter 4.

overview of the results		**OPTIMISATION**							
IC Berlin		09.08.2015							
Service		**acer**	**Mac**	**Vaio**	**Vaio**	**Soc**	**Acer**	**Soc**	AVERAGE
Demand									
Train demand per day	[#]	15,054	15,202	15,863	15,171	15,056	15,863	15,245	15,351
deviation from average		**2%**	**1%**	**-3%**	**1%**	**2%**	**-3%**	**1%**	
standard deviation									357

Appendix K. Network 2015 (Deutsche-Bahn)




ICE-Netz 2015
Gültig vom 14. 12. 2014 bis 12. 12. 2015
DB BAHN
ICE-Linien
Linie 10, 47, 84 (TGV)
Linie 11, 31, 81 (TGV)
Linie 12, 91
Linie 20, 80 (THALYS)
Linie 22
Linie 25, 79
Linie 28, 43
Linie 41, 83 (TGV)
Linie 42
Linie 45, 82, 90 (Railjet)
Linie 49, 76
Linie 50
Linie 75, 78
1) L 10 Halt im 2 Std-Takt
2) L 11 kein Halt
3) L 28 Halt im 2 Std-Takt
4) Ostseebad Binz - Stralsund saisoniert
5) Nürnberg - Passau nur Fr-So
ICE-Bedienung
Linie im 1-Stunden-Takt
Linie im 2-Stunden-Takt
Linie im 4-Stunden-Takt
Einzelne Züge
Systemhalte
ICE-Sprinterzüge und ICE-Züge mit abweichenden Laufwegen sowie zusätzliche Tagesrandhalte sind nicht dargestellt
Århus
Padborg
Flensburg
Schleswig
Rendsburg
Kiel
Neumünster
København
Puttgarden
Warnemünde
Oldenburg (H)
Rostock
Stralsund
Ostseebad Binz
Bergen (Rügen)
Greifswald
Züssow
Anklam
Lübeck
HH-Altona
HH Dammtor
Hamburg Hbf
HH-Harburg
Waren
Neustrelitz
Pasewalk
Prenzlau
Angermünde
Eberswalde
Bremen
Oldenburg (Oldb)
B-Gesundbrunnen
Berlin Hbf
B Ostbahnhof
B-Spandau
B Südkreuz
Wolfsburg
Hannover
Minden
Osnabrück
Herford
Bielefeld
Gütersloh
Helmstedt
Magdeburg
Braunschweig
Hildesheim
Amsterdam
Münster
Dortmund
Bochum
Essen
Oberhausen
Duisburg
Hamm
Soest
Lippstadt
Paderborn
Altenbeken
Warburg
Lutherstadt Wittenberg
Köthen
Halle
Leipzig/Halle Flugh.
Göttingen
Naumburg
Leipzig
Riesa
Dresden-Neustadt
Dresden Hbf
Düsseldorf Flugh. Fernbf
Düsseldorf Hbf
Solingen
Hagen
Wuppertal
Köln Hbf
Köln Messe/Deutz
Kassel-Wilhelmshöhe
Bebra
Eisenach
Erfurt
Gotha
Weimar
Jena Paradies
Bruxell./Brussel
Aachen
Köln/Bonn Flughafen
Siegburg/Bonn
Montabaur
Bad Hersfeld
Fulda
Saalfeld
Bruxelles/Brussel
Paris Nord
Bonn
Frankfurt (M) Hbf
Hanau
Limburg Süd
Koblenz
Wiesbaden
Mainz
F Süd
Aschaffenburg
Lichtenfels
Bamberg
F Flugh. Fernbf
Darmstadt
Würzburg
Erlangen
Nürnberg
Mannheim
Kaiserslautern
Saarbrücken
Neustadt
Homburg
Heidelberg
Paris Est
Regensburg
Karlsruhe
Stuttgart
Plattling
Passau
Strasbourg
Baden-Baden
Offenburg
Ingolstadt
Ulm
Augsburg
Wien Hbf
Flughafen Wien
Lyon
Marseille
M-Pasing
München Hbf
Wien Westbf
Wien Hbf
Budapest Keleti
Mulhouse
Freiburg
Tutzing
M-Ost
Rosenheim
Salzburg
Murnau
Oberau
Garmisch-Partenkirchen
Kufstein
Paris Gare du Lyon
Basel Bad Bf
Basel SBB
Mittenwald
Innsbruck
Zürich
Bern
Interlaken Ost
Seefeld i. T.
Kartografie: DB Netz AG, Zentrale, I.NVT 52 (V)
Im Galluspark 23, 60326 Frankfurt am Main
Redaktion: DB Fernverkehr AG
P.FBZ 22 (We)
Stand: November 2014

Appendix L. SCBA references

Based on the SCBA of the projects OV-SAAL (Schiphol, Amsterdam, Almere, Lelystad), Breda-Utrecht and the Zuiderzeelijn, the infrastructure kilometres price is determined. The projects are chosen, as they are either recent (Breda-Utrecht), or provide infrastructure for higher speeds (OV-SAAL and Zuiderzeelijn). The price per kilometre is calculated in Table L-1:

In column D, the infrastructure length is presented in kilometre. Column E presents the result of the conducted SCBA. Additional measures as the building of new stations are subtracted from the costs (H). By dividing these costs through the infrastructure length (H/D), provides the costs for one kilometres double track (one per direction). We assume that the costs for one kilometre single track (only one railway instead of two), are relatively higher than the construction of two tracks (factor 1.3; column J). Based on the price per kilometre double track (M), the maintenance costs are calculated as a percentage of the investment costs (N). Each project refers to a price level and a discount factor. Based on this information both, investment and maintenance costs are recalculated for the year 2015.

Since the infrastructure alternative requires also the adjustments of 12 stations, the average price of two currently built stations are used. Both prices, the infrastructure per kilometre and the stations, are annually discounted until 2024. The complete infrastructure costs, discounted over 30 years, are presented in Table L-2.

Table L-1: Infrastructure costs per kilometre – based on Dutch projects.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
reference projects	measures	speed	km of construction	*total costs*	*number of stations*	*station costs*	*delta costs*	cost/km double	additional tracks	costs/km single	factor for existing	*price km double*	*mainten-ance share*	*mainten-ance costs*	price level	scope	discount factor	PRICE infra 2015	annual main-tenance 2015	special	Source
		km/h		*in mio*		*in*	*in mio*						*%*	*per*			%	*(1+q)^t*	*(1+q)^t*		
TRACKS			1.8	*101*																	Quick Scan Maatschappelijke Kosten / Baten-Analyse
			3.1	*211*																	
			3.9	*364*																	
OV-SAAL	add 2 tracks	200	8.8	*676*	1	*40*	*636*	72	1.3	55.6	0.7	***50.6***	***2.5%***	***16.9***	2007	2100	5.5%	**77.6**	**25.9**	in city	
												-									
Breda-Utrecht	2 new tracks	140	70	*3050*	7	*70*	*2980*	43	1.3	32.7	1	***42.6***	***1.0%***	***30.5***	2010 ?	2080	5.5%	**55.6**	**39.9**	7 new? stations	MKBA spoorlijn Breda – Utrecht Eindrapport
												-									
Groningen-Emmen	single track new	60	19				*0*	5.25		3.8	1			***na***	2009 ?	na	4.0%	-	-	1 new track, 3 new stations	Maatschappelijke Kosten-Baten Analyse van Nieuwe Spoorverbindingen tussen Groningen en Emmen
	double tracks							5.25				-									
Zuiderzeelijn	additional tracks; double??	250	130	*5100*	2	*20*	*5080*	39	1.3	30.1	1	***39.1***	***0.6%***	***30.0***	2005	2100	5.5%	**66.7**	**51.2**	250 km/h HST 1, 2 new	KBA Openbaar Vervoer-alternatieven Zuiderzeelijn
Total												-						**66.7**	**39.0**		
STATIONS																					
Westervoort	build small stations			*10*											2011		5.5%	**12.4**			http://www.stadsregiorail.nl/nieuws/betere-bereikbaarheid-met-station-westervoort.aspx
Heneglo gezondheidspark	build small stations			*5*											2012		5.5%	**5.9**			http://www.tubantia.nl/regio/hengelo-en-omgeving/bouw-station-gezondheidspark-in-volle-gang-1.1736595

Table L-2: The infrastructure costs discounted over 30 years.

Infra alternative

price level	**2015**	costs per unit	**Netherlands**	Germany	Berlin-Hannover ICE	**Total**
time period in years	**30**					
Costs [€]		**in mio**	169	206	250	**625**
DIRECT						
Investment costs (NL+DE)						
ProRail, DB Netz, I&M, ministries DE						
Infrastructure						
Tracks	**€**	**- 51,309,426**	**- 8,671,292,993**	**- 10,569,741,755**		**- 19,241,034,748**
Stations	#		6	6		
Stations	**€**	**- 4,518,060**	**- 27,108,362**	**- 27,108,362**		**- 54,216,724**
Operational costs (NL+DE)			share	share		
NS, DB	%		0.33	0.67		
Maintenance	**€**	**- 6,238,444**	**- 2,079,481**	**- 4,158,963**		**- 6,238,444**
Total	€					**- 19,301,489,916**

IC Berlin		30 years		Discount factor:	5.5 %	
			ALTERNATIVES			
1	2	4	5	6	7	8
Item		**Infrastructure**	**Rolling stock**	**Network**	**Revenue**	**Optimisation**
Governemental CBA						
External effects		0	0	0	0	0
CO_2 reduction car		2	1	0.2	0.1	0
CO_2 reduction airplane		5	1	0.2	0.1	0
PM items	***€??***	***0***	***0***	***0***	***0***	***0***
Benefits NS		7	2	0	0	0
NPV	[mln.€]	**7**	2	0.4	0.3	0
Delat ratio		n.a.	n.a.	n.a.	n.a.	n.a.
Passenger CBA						
Money savings		0	0	0	41	0
Time savings		188	28	24	0	0
Benefits	[mln.€]	**188**	28	24	**41**	0
NS CBA						
Costs NS		-116	-6	-76	0	0
NS national revenue	0	46	5	-1	-3	2
NS international revenue	1	95	11	-3	-7	4
Benefits NS		141	17	-4	-10	6
NPV	[mln.€]	26	11	-81	-10	6
B/C ratio		1.2	**2.8**	n.a.	n.a.	~6
DB CBA						
Costs DB		-232	-12	-153	0	0
DB national revenue	0	0	0	0	0	0
DB international revenue	0	187	22	-5	-13	8
Benefits DB		187	22	-5	-13	8
NPV	[mln.€]	-44	11	-158	-13	8
B/C ratio		0.8	**1.8**	n.a.	n.a.	~6

The minimum (netto) rolling stock calculation is based on travel time, turnaround time at the end station and the daily operating hours. For the IC Berlin are these: 6.3h*2 travel time, 1.75 hours turnaround time including cleaning process, 18 hours operation time, 0.5 frequency per hour. For the reference case reveals this: (6.3h*2 + 1.75h*2) / 0.5 ~ 9 train set (netto). The gross margin (brutto) is communicated with NS with 30%. This reveals in 9*1.3 = 12 locomotives. The prices, highlighted in yellow, are equally approximations from colleagues.

Table L-3: Rolling stock calculation.

Rolling stock									
Reference locomotovtives (also for Network and Fare alt)					6.3				
new train set	€	-12,000,000			loc netto	loc brutto	wagons	total	
train sets	#	***12***	**-144,000,000**	€	9	12	9	108	
					calculation : (travel time both directions + turnaround time both end stations) / frequnecy				
Infrastructure rolling stock ICE					3.7				
new train set	€	-35,000,000			loc netto	loc brutto	wagons	total	
train sets	#	***8***	**-280,000,000**	€	6	8	9	72	
rolling stock alternative IC 230					5.8				turnaround tir
new train set	€	-15,000,000			loc netto	loc brutto	wagons	total	1.75 hours
train sets	#	***11***	**-165,000,000**	€	8	11	9	99	
Network alternative									
new train set	€	-12,000,000			loc netto	loc brutto	wagons	total	
train sets	#	***20***	**-240,000,000**	€	15	20	9	180	

Appendix M. SENSITIVITY ANALYSIS

The sensitivity analysis is conducted using the following elasticities.

Table M-1: Sensitivity values.

Elasticity values

	Pessimistic					Reference					Optimistic
	-90%	-70%	-50%	-30%	-10%	**0%**	10%	30%	50%	70%	90%
Frequency elasticity	-0.02	-0.06	-0.10	-0.14	-0.18	**-0.2**	-0.22	-0.26	-0.30	-0.34	-0.38
Travel time elasticity	-0.06	-0.18	-0.30	-0.42	-0.54	**-0.6**	-0.66	-0.78	-0.90	-1.02	-1.14
Fare elasticity	-0.08	-0.24	-0.40	-0.56	-0.72	**-0.8**	-0.88	-1.04	-1.20	-1.36	-1.52

Based on the pessimistic values, the international LVM is used to model both, the revenue and rolling stock alternative. Afterwards the new passenger numbers and passenger kilometres are inserted in the evaluation spreadsheet, to show the costs and benefits. See next table.

	SENSITIVITY ANALYSIS		**Rolling stock alternative**						
	Item		**reference case**	**0%**	**-10%**	**-30%**	**-50%**	**-70%**	**-90%**
1	Cost	Unit							
2	Investment costs (Infrastructure)		-	0	0	0	0	0	0
5	Investment costs (new rolling stock)		-	-20	-20	-20	-20	-20	-20
8	Operational costs		-	0	0	0	0	0	0
11	**Total costs**	**[M.€]**	-	**-20**	**-20**	**-20**	**-20**	**-20**	**-20**
13	Benefits								
14	*Operators*								
15	Income ticket sale		-	40	40	30	30	30	30
21	*Passengers*		-						
22	Money savings		-	0	0	0	0	0	0
25	Travel time savings		-	30	30	30	30	30	30
40	**Total benefits**	**[M.€]**	-	**70**	**70**	**60**	**60**	**60**	**50**
42									
43	**Net Present Value**			**50**	**50**	**40**	**40**	**40**	**30**
44	**Benefit/cost ratio**			**3.5**	**3.5**	**3.0**	**3.0**	**3.0**	**2.5**

Appendix N. List of abbreviations

OD - Origin-Destination

GC - Generalized costs

GJT - Generalized journey time

EMU - Electrical multiple unit

PAX - passenger

Stations– IC Berlin	
asd	Amsterdam
hvs	Hilversum
amf	Amersfoort
apd	Appeldoorn
dv	Deventer
aml	Almelo
hgl	Hengelo
hbth	Bad Bentheim
HR de	Rheine
HO	Osnabruck
HOY	Bad Oeynhausen
HBDE	Bünde
HM de	Minden
HH	Hannover
HWOB	Wolfsburg
LS	Stendal
Ber	Berlin Hauptbahnhof