Y. Dekker

The effects of Buses with High Level of Service on ridership and operations

A Dutch case study

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The effects of Buses with High Level of Service on ridership and operations

A Dutch case study

By

Youri Dekker
5070996

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Thesis committee:	Dr. Ir. N. van Oort,	TU Delft (Chair)
	Dr. Ir. A. Gavriilidou,	TU Delft (Daily supervisor)
	Ir. J. de Lanoy,	EBS Public Transportation B.V.

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Preface

The bus is an amazing mode of transport. This is something I rarely hear someone saying, but I think it is true. The bus brings you from A to B while you can read a book or listen to your favourite podcasts. Before you know, you arrive at my destination. In metropolitan regions that are getting more crowded, the bus is a space efficient alternative for the private car. Next to that, the bus is a mode of transport with relatively few emissions per passenger kilometre. This makes the bus a future proof transport mode.

If in 2019, when I started my studies in Civil Engineering at the TU Delft, anyone would have told me that would do a thesis on buses, I would have laughed at them. I have always been a big fan of trains, and I was a 100% sure that I was going to do something with that as a topic. During my journey at the university, I have learned that buses are at least as interesting as trains. The course Systems and Supply Planning and Operations (also called 'syspo') by Niels van Oort seriously contributed to my growing interest in bus transit. A rhythmic timetable and a bus that is at the right place at the right time; it seems so simple. Now that I learned more about the complex systems behind this, I start to realise that a good functioning public transport system like we have in the Netherlands is a miracle.

During my studies, and particularly during my thesis, I have learned a lot about bus transit. I am really looking forward to putting this knowledge into practice. My ambition is to make bus transit even better than it is already so that in the end more people will agree with me when I say that the bus is an amazing mode of transport.

Writing my thesis was a great experience. At no other point during my studies, I felt so supported by the people around me. I am thankful for everyone who contributed to this. I would like express gratitude to Niels van Oort in the first place for getting me excited for bus transit, but also for his input as chair of the thesis committee. I would also like to thank Alexandra Gavriilidou for the inspiring conversations and her critical view which had a great positive impact on the final result. Of course, I would also like to thank EBS for giving me the opportunity to my thesis at the company. I have felt very welcome from day one. Special thanks to Jasper de Lanoy who was my company supervisor. Also, a special thanks to Julius van Boldrik who helped me out by providing essential information about the impact of a BHLS fleet on the operations.

Youri Dekker

Nieuw-Vennep, July 2025

Summary

In many countries around the globe, high-quality bus services are being implemented (Odijk, 2024; van der Bijl & van Oort, 2024). Also in the Netherlands, bus operators have implemented services that are classified as Buses with a High Level of Service, BHLS (also Hoogwaardig Openbaar Vervoer, HOV, in Dutch) (CROW-KpVV, 2024). Upgrading conventional services to BHLS can lead to large ridership increases and modal shift rates from the car to the bus of up to 30% (Finn, et al., 2011). A modal shift from the car to the bus contributes to reducing carbon emissions in transportation (European Environment Agency, 2022).
The objective of this work is to develop knowledge on the importance of BHLS aspects with respect to ridership and advise bus operators and transit authorities about the implementation of BHLS aspects. The main research question reads:

Which aspects of BHLS are most critical when upgrading conventional bus services to gain ridership while considering the operational efficiency?

First, the aspects of BHLS are determined based on a literature review. Then, the performance of bus lines on these BHLS aspects is assessed in a Dutch case study to investigate how BHLS in practice relates to the findings in literature. This is done for BHLS services as well as conventional services. The performances of the different services are compared to each other to explore what BHLS means in practice and how that relates to literature. Once the performance of each line is assessed, the relation of the BHLS aspects with ridership is investigated. This is done using a multiple linear regression model. Lastly, the impact of the deployment of dedicated BHLS vehicles on the operational efficiency is researched. Two sets of vehicle schedules are developed for a scenario where all lines are carried out by one single vehicle type and for a scenario where BHLS services have their own dedicated fleet. A framework is developed which can be used to estimate how much ridership should increase to cover the costs of a dedicated fleet.

BHLS in literature and in practice

The literature review revealed what BHLS should be according to the theory. Based on the findings in the review, it can be concluded that BHLS should be:

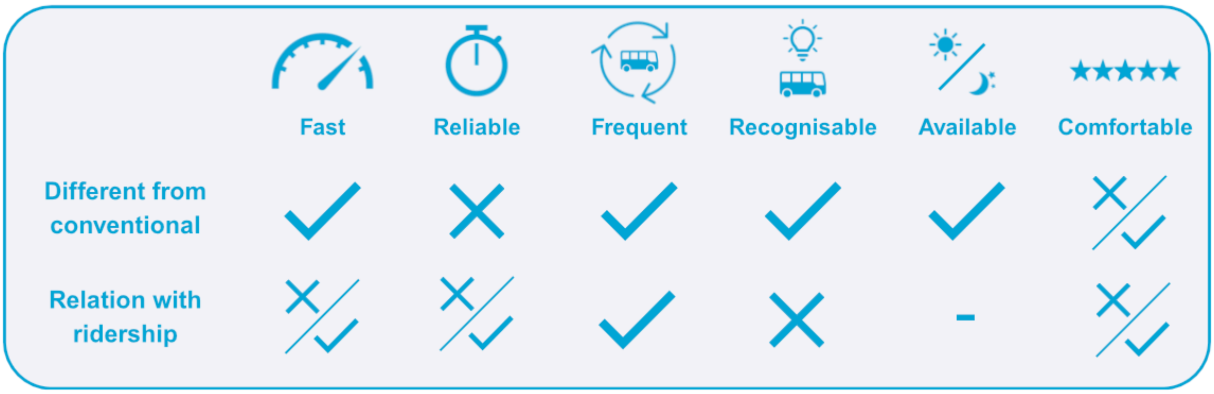
- Fast, because of a low stop density and dedicated road infrastructure
- Reliable, because of dedicated road infrastructure
- Frequent
- Recognisable, because of a dedicated identity
- Available, due to wide operation hours
- Comfortable, because of a good stop design, dynamic traveller information, and a high in-vehicle seat availability

The performance of BHLS services is compared to that of conventional services on the network of EBS, covering four concession areas in the Netherlands. Three of the concession areas are in the densely populated Randstad area and one in in the eastern, less populated part of the country. The comparison showed that in in the case study area, not all aspects of BHLS are put to practice. In practice, BHLS has a higher operational speed, a higher frequency throughout the day, and a different branding and colour scheme compared to conventional services. In some regions, the stops along BHLS lines are more comfortable with features like shelters, dynamic travel information

panels or bicycle parking facilities. When it comes to the seat availability on board, no difference between conventional services and BHLS is observed. Also, no improvement in the reliability of BHLS are observed considering the punctuality and cancellation rate.

Relation of BHLS aspects with ridership

Not all aspects of BHLS have a significant relation with ridership in the case study area. The speed, which is a pronounced aspect of BHLS in literature as well as in practice, does not show an unambiguous relation with ridership from which general conclusions can be drawn. The relation was positive in some cases but negative in others. When it comes to the reliability, a slight negative relation is observed for off-peak cancellation rates. This indicates that ridership is lower on services that are cancelled more often during the off-peak hours. The other part of reliability, the punctuality, does not show any significant relation with ridership at all. On the other hand, the frequency has a strong positive relation with ridership. Therefore, it is good to see that this important aspect from the literature is also put to practice in the case study area. Something else which is put to practice is the recognisability of BHLS by deploying dedicated vehicles. However, there is no relation with ridership observed for the deployment of these BHLS vehicles. The frequency at different moment of the day is chosen as an indicator for the availability due to wide exploitation hours. Because frequencies for different moments of the day are highly correlated with each other, the relation between availability and ridership cannot be investigated in the regression model. The comfort is divided in two parts, the stop design including dynamic traveller information, and the seat availability. When it comes to the stop design, a positive relation between the share of stops with a shelter and ridership is observed. Bicycle parking facilities and dynamic traveller information panels do not show significant relations. Because the seat availability is very strongly related to ridership, this comfort aspect is not included in the regression model.
The results of the comparison and regression model can be summarised in the graphic below.



Overview comparison and regression. ✓ yes × no ×/✓ some areas/moments yes, others no - excluded from model

Effects of a dedicated BHLS fleet on the operations

The recognisability of BHLS is put to practice in all concession areas in the case study area, but there is no relation with ridership observed. A framework is developed to estimate what the costs of a dedicated fleet are and what the ridership increase should be on the BHLS lines to cover the extra costs. The costs consist of the depreciation of extra vehicles that are needed and costs due to a decrease in the efficiency of the vehicle deployment. The required ridership gains to cover these costs are calculated based on average income per trip.

Sets of vehicle schedules are developed for two examples to explore the magnitude of the impact on the operations. In the examples, 2.3 to 3.7% extra buses are needed because limitations in the vehicle deployment. BHLS vehicles are preferably not deployed on conventional lines and conventional vehicles not on BHLS lines. The efficiency which is determined as the in-service time of vehicles divided by the total vehicle time decreases with a few tenths of a percent due to the separation in fleets.

The information from the two examples is used as input for the cost to estimate the required ridership gains. The depreciation of the extra vehicles turned out to have the largest share in the costs for a BHLS fleet. In the case study area, attracting about 1.3% more passengers could cover the costs of a dedicated fleet. Based on the case study data, there is no proof that a dedicated fleet leads to this ridership increase.

Conclusion

All things considered, the frequency, shelters, and low cancelation rate are the most critical aspects of BHLS to gain ridership. The advice towards operators and transit authorities would therefore be prioritise improving the frequency and place shelters along the line once upgrading services to BHLS. Also, minimisation of the cancellation rate is recommended. Other aspects of BHLS do not show a direct relation to ridership but should not be neglected because they could improve the overall image of bus transit. The implementation of a dedicated BHLS fleet is only recommended if there are reasons to expect ridership gains in the order of magnitude of 1.3%. Suggestions to realise such an increase are the development of a strong brand which is recognisable as being of high-quality, a consistent application of this strong brand, and an improved level of on-board quality in BHLS vehicles. The exact effectiveness of these suggestions should be investigated in future research.

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List of Abbreviations

AFC	Automated Fare Collection
AVL	Automated Vehicle Location
BHLS	Bus with High Level of Service
BRT	Bus Rapid Transit
CHB	Centraal Halte Bestand (central station record)
DRIS	Dynamisch Reizigersinformatiesysteem (dynamic traveller information system)
EBS	EBS Public Transportation B.V.
GDP	Gross Domestic Product
HOV	Hoogwaardig Openbaar Vervoer (high-quality public transport)
IJV	IJssel-Vecht
LRT	Light Rail Transit
MRDH	Metropoolregio Rotterdam Den Haag (Metropolitan Region Rotterdam The Hague)
SEM	Structural Equation Modelling
ZaWa	Zaanstreek-Waterland

1 Introduction

In many countries around the globe, high-quality bus services are being implemented (Odijk, 2024; van der Bijl & van Oort, 2024). Many of those bus services have a branding that makes them distinguishable from other bus services (e.g. *TransMilenio* in Bogotá and *Trans-Val-de-Marne* in Paris/Île-de-France). The same can be observed in the Netherlands. When visiting a Dutch bus station, it is likely to encounter a variety of brands for buses. Many operators give different types of services a different name and look. Qbuzz for example, uses the brands *R-net*, *snelBuzz*, *streekBuzz*, *stadsBuzz*, and *buurtBuzz* in some of their concession areas (Qbuzz, 2024). Most Dutch operators have at least one distinctive brand reflecting a service that can be categorised as HOV (CROW-KpVV, 2024). HOV is a Dutch concept that stands for "Hoogwaardig Openbaar Vervoer" which translates to High-Quality Public Transport. This can be compared to the international term BHLS (Buses with High Level of Service). The difference between the two is that the use of the term HOV is not restricted to only buses. It is also used for tram, light rail, metro, and even train services. Since this research only focuses on buses, the international term BHLS is used to indicate high-quality bus services. In the Dutch Randstad area, *R-net* is the most common brand for BHLS. *R-net* vehicles are recognizable by their typical grey-red colour scheme (Figure 1.1). In contradiction to for example Qbuzz' own *snelBuzz* branding (Figure 1.2), the *R-net* branding is adopted by many different operators and modes (R-net, 2023).

Figure 1.1 R-net in Delft

Figure 1.2 snelBuzz in Utrecht

1.1 Scientific relevance

A lot of high-quality bus services have been evaluated (Finn, et al., 2011; Heddebaut, et al., 2010; van der Bijl & van Oort, 2024). In most case studies, a strong ridership increase is observed as result of the implementation of BHLS. Heddebaut, et al. (2010) observe a ridership increase of 20 to 134% as an effect of the implementation of high-quality bus services. Finn, et al. (2011) observe similar numbers for the increase of ridership: 15 to 150%. From these works alone, it becomes clear that high-quality bus systems are far from the same. Not all considered systems have the same set of features. Also, the performance of different systems differs a lot. Although the implementation of BHLS has for example led to a higher operational speed in all their case studies, Finn, et al. (2011) observe that the improvements compared to the original situations vary a lot. The performance differences might be one of the explanations for the wide range of observed ridership increases. Because of the large differences between the systems and the loose definition of BHLS, it would be incorrect to state that BHLS itself is the driver of the growing number of passengers. BHLS should be seen as a concept with a set of features a bus service could comply with. Those individual features are the drivers of the ridership increase.

From literature, it does not become clear to what extend individual BHLS aspects contribute to this ridership growth. Heddebaut, et al. (2010) mention the change in number of vehicle-km, operating speed, headways, network structure, fares and a unique branding in combination with marketing as likely factors for an increased ridership. However, they state that "there is an extreme shortage of structured research into the individual and linked factors that achieve the ridership gains." Finn, et al. (2011) explicitly mention that the effect of branding for BHLS should be further investigated.

Borsje, et al. (2023) address this shortage with a discrete choice experiment among potential travellers in the Netherlands (n = 1019). In their research, respondents are asked to choose between different configurations of high-quality bus services that perform different on particular aspects. The result of the experiment is a list of aspects with their relative importance compared to other aspects, and the preferred level of performance for each aspect. Those aspects are: frequency, availability, stop spacing, reliability, stop type, running ways, vehicle type, and colour palette.

Chen, et al. (2024) also address the shortage described by Heddebaut, et al. (2010) with research on strategies to attract more bus passengers after the ridership decrease during the COVID-19 outbreak. In their research, they ask transit agency managers from the United States in a survey (n = 244) which strategies they have implemented to gain ridership before and during the pandemic and which strategies they are planning to implement in the years to come (post-pandemic). Then, the transit agency managers are asked to estimate how effective these strategies are on a scale from 1 (not effective at all) to 5 (extremely effective). The transit agency managers estimate that an increased service frequency is the most effective strategy to gain ridership out of all 35 proposed strategies.

Although these works partly cover the shortage described by Heddebaut, et al. (2010), they do not fully explain which aspects of BHLS are the driver of the ridership increase as there is no link to actual ridership data. This work intents to do so by first defining what BHLS is and then investigate the relation between BHLS characteristics and ridership based on case study data. Extra attention will be paid to the branding and identification of BHLS to address the shortage described by Finn, et al. (2011).

1.2 Societal relevance

The knowledge that flows from the research could be of great value for bus operating companies and transit authorities. It helps to understand what the focus points should be when introducing a new BHLS service or upgrading an existing service. The knowledge can be used to make smarter and more effective investments in BHLS. Further improving the quality of BHLS services makes travelling by bus more attractive for excising travellers as well as for potential new travellers. Finn, et al. (2011) observe a model shift rate from the car between 5 and 30% when introducing a BHLS service. Such a modal shift can be of great value for some societal problems and goals.

First, the modal shift can play a role in the solution to climate change. In the European Union, about 25% of CO_2 emissions (2019 data) came from transport (European Parliament, 2024). Over 60% of those transport emissions were caused by car traffic. Emissions per passenger-kilometre are substantially lower for bus travellers compared to car travellers (European Environment Agency, 2022). From a climate perspective, it would therefore be advantageous to aim for a model shift from the car to the bus. Introducing BHLS can help with that.

Next to the environmental benefits, BHLS also has efficiency benefits over the privately owned car. A bus can transport way more passengers from A to B per square metre than cars. An extreme example illustrated in Figure 1.3. The figure shows how much space would be needed if a group of people would travel by car or by bus. This, of course, only goes up if enough people use the bus. A well occupied bus can be 12 times more space efficient than a passenger car (de Dios Ortúzar, 2019). The high spatial efficiency could help to reduce congestion which is perceived as an unacceptable issue by about 35 percent of the Dutch population (KiM, 2020). Next to that, shifting towards the more space efficient bus could free up space for more urban greenery and for the safe use of active modes. This can be a step towards creating sustainable, future-proof cities that are nice to live in.

Figure 1.3 Spatial efficiency of the bus (source: de Dios Ortúzar, 2019)

1.3 Objective and Research Questions

The objective of this research is to develop knowledge by covering the research gap and advise operators or transit authorities which aspects should get the most attention when implementing BHLS. The advice is based on the relations between individual BHLS aspects and ridership. These relations reveal which aspects affect the ridership increase as found by Heddebaut, et al. (2010) and Finn, et al. (2011).

However, there might also be disadvantages for operators when introducing BHLS. For example, a dedicated fleet for BHLS entails restrictions in operational planning. For instance, buses with a BHLS branding should not be deployed on conventional bus lines. This means that more buses might be needed to run all services from the timetable. A dedicated fleet thus negatively impacts the operation costs (Finn, et al., 2011). Therefore, the effects on the operations of applying a BHLS brand are also considered in the advice towards operators or authorities. After all, the potential extra costs due to operational constraints should play an important role in the decision-making process.

The above-described objective leads to the following research question: *Which aspects of BHLS are most critical when upgrading conventional bus services to gain ridership while considering the operational efficiency?*
To answer this question, five sub-questions have been set up:

1. *What are relevant aspects that distinguish BHLS bus services from conventional bus services according to literature?*

The answer to this question is a list of aspects that distinguish BHLS from conventional bus services. These are the aspects of which the relation to ridership is investigated.

2. *How does the performance of BHLS services compare to the performance of conventional bus services on BHLS aspects?*

The answer to this question is a set of descriptive statistics that shows the differences between conventional bus services and BHLS services. The performance assessments are also used as input for the model used for analysing the relation between BHLS and ridership. Furthermore, the statistics reveal the difference between BHLS services in literature and in practice.

3. *What is the relation between individual BHLS aspects and ridership?*

The answer to this question is the output of a model that explores the relation between the aspects as defined in the answer to the first sub-question and ridership. The interpretation of these results partially leads to the answer to the main research question.

4. *What is the impact of deploying dedicated BHLS vehicles on the operational efficiency?*

The introduction of a BHLS service with a dedicated fleet may have a negative impact on the operational efficiency as those vehicles are (preferably) not deployed on conventional lines. This limits the possibility to deploy vehicles on multiple lines to avoid long turnaround times at the endpoints of the line. The answer to this question gives an indication of what the impact on the operational efficiency of such a dedicated fleet is. The effect on the operational efficiency might be an important factor when deciding on the implementation of BHLS.

5. *What does a framework look like to estimate the required ridership gains to reach a break-even point for a cost-effective BHLS fleet?*

If aspects that require a dedicated fleet (e.g. a distinctive vehicle branding) turn out to have a negative impact on the operations, extra costs are made. The answer to this question is a framework that can be used to estimate the costs of a dedicated fleet and the ridership gains that should be realised to cover those costs.

1.4 Scope

The answers to the research questions will partially be based on case study data. The case study data mainly consists of AFC and AVL data. However, AFC data are not publicly available. Therefore, this research is conducted in collaboration with Dutch bus operating company EBS Public Transportation B.V. (EBS). The collaboration enables using real-world data to perform the analysis. The available data is limited to the four concession areas of EBS. Those concession areas are Zaanstreek-Waterland, Haaglanden Streek, Voorne-Putten & Rozenburg, and IJssel-Vecht (EBS OV (1), 2024). The combination of those concession areas will form the case study area. More details on the case study area can be found in Section 4.
Although external factors affect ridership, they will not be considered in the model which will be used to investigate the relation between BHLS aspects and ridership. Including all aspects that may influence ridership would make the model overly complex and would require an enormous sample size. Therefore, only the aspects of BHLS will be considered when modelling the relation with ridership.

1.5 Thesis outline

This report continues with determining the aspects of BHLS based on a literature review in Chapter 2. Then, the methodology for the rest of this work is described in Chapter 3. In Chapter 4, the case study area is explained. This includes a description of all different service types in the considered regions. The performance of BHLS services is compared to that of conventional services in Chapter 5. This gives insight in how BHLS performs in practice and how that compares to the aspects of BHLS from literature. A model is developed to analyse the relation between BHLS aspects and ridership and in Chapter 6. The model reveals which aspects have a significant relation with ridership and how strong that relation is. In Chapter 7, the effects of a dedicated BHLS fleet are discussed. In this chapter, an estimation is done what the costs of a dedicated fleet are and what ridership gains on BHLS lines should be to cover those costs. The answers to the research questions and recommendations can be found in Chapter 8.

2 BHLS in Literature

The first sub-question is answered in this chapter based on literature. A literature review is performed in Section 2.1. In Section 2.2, the aspects of BHLS found in the literature review are clarified and positioned in the pyramid of customer needs. The aspects are brought back to a set of targets in Section 2.3.

2.1 Literature review

A literature review is performed to determine which characteristics distinguish BHLS services from conventional bus services. The platforms used for finding literature are Google Scholar, WorldCat, and the repository of the TU Delft. The search terms are displayed in Table 2.1. The first column indicates the base of the search terms. All searches included one of the keywords from this column. In addition to that, keywords from the second column have been added to the search terms. This is done in such a way that all possible combinations have been made. Potential aspects of BHLS (e.g. frequency or reliability) have not been included in the search terms as this might bias the outcome of the review. Actively searching for certain aspects may overestimate the importance of those aspects.

Table 2.1 Search terms literature review

Base	***Addition***
Hoogwaardig Openbaar Vervoer / HOV	Examples
Bus High Level Service / BHLS	Case study
High Quality Bus	Characteristics
	Europe
	Ridership

A reviewed work is considered relevant once the concept of BHLS is being described. Relevant works are evaluated on addressing a set of aspects of BHLS. The initial set of aspects is made up based on findings in the first reviewed work. Along the way, the list of aspects is extended based on new findings. After all works has been reviewed, a final assessment round is performed with the complete list of aspects. The threshold of an aspects being addressed is that the aspect should be mentioned as a characteristic of BHLS. The presence of an aspects does not have to be proven by the work. This choice is made because the aim of the review is to get a theoretical definition of BHLS. In Chapter 5 of this report, the performance of BHLS is evaluated in a Dutch case study. The results from that chapter reveal which of the BHLS aspects are put to practice in the case study area. The results from the literature review are presented in Table 2.2. The last row indicates how many works address the aspects from the title row.

Table 2.2 Literature overview BHLS aspects

Scope of the reviewed work
Aspects considered

Source	BHLS/HOV	BRT	Ridership	Dutch Example	European Example (excl. Dutch)	Operational speed	Reliability	Dedicated infrastructure	Frequency	Identity	Seat availability	Stop comfort	Dynamic traveller information	Stop density	Operation hours
Bodok, Ebbink, & Roos, 2011	x		x	x	x	x	x	x	x	x	x	x	x		x
Borsje, et al., 2023	x	x	x	x		x	x	x	x	x		x		x	x
Eichler, 2023	x	x	x	x		x	x	x	x	x	x	x	x	x	x
Fadaei & Cats, 2016	x		x		x	x	x	x	x		x			x	
Finn, et al., 2011	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Heddebaut, et al., 2010	x	x	x	x	x	x	x	x	x	x	x			x	
Hidalgo & Gutiérrez, 2013	x	x	x		x	x	x	x							
Odijk, 2024	x	x	x	x	x	x	x	x	x	x		x	x	x	x
van der Bijl & van Oort, 2024	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
van der Scheer, 2016	x	x	x	x		x	x	x	x	x	x	x	x		
van Woerkens, 2014	x			x		x	x	x	x	x	x	x	x		
Count (out of 11)	***11***	***8***	***10***	***9***	***7***	***11***	***11***	***11***	***10***	***9***	***8***	***8***	***7***	***7***	***6***

From the literature, it becomes clear that the Dutch HOV concept for buses is the equivalent of the international term BHLS. However, there is no consensus about the definition of HOV/BHLS. It is sometimes referred to as the European version of Bus Rapid Transit (BRT) (Borsje, et al, 2023). As reflected in Table 2.2, BRT and BHLS are often treated within one paper. Yet, BRT and BHLS are not the same thing. The focus of BRT is on providing a fast and high-capacity bus service. If well-implemented, it could achieve metro-like performances (Finn, et al., 2011). BHLS on the other hand, positions itself between a conventional bus service and Light Rail Transit (LRT) (Hidalgo & Gutiérrez, 2013). Besides providing a higher capacity compared to a conventional bus, BHLS also focusses on improving customer satisfaction.
Works that include case studies show that the performance of BHLS services can vary a lot. Finn, et al. (2011) therefore write about weak and strong BHLS. Whether a service is considered as weak or strong depends on the extend of the implementation of BHLS aspects. Van der Bijl and van Oort (2024) introduce an additional bus type: Bus Plus, comparable with weak BHLS. Bus Plus is a conventional bus service with an increased vehicle capacity or increased frequency. It does not necessarily come with BRT or BHLS features like dedicated infrastructure or a high operational speed.

2.2 Aspects of BHLS from literature

In this section, the aspects that contribute to the concept of BHLS from Table 2.2 are described. Also, it is described where each of the aspects position themselves on the pyramid of customer needs by van Hagen (2011). The pyramid of customer needs as developed by van Hagen (see Figure 2.1) is an application of Maslow's Hierarchy of Needs on train station designs. To make the pyramid applicable for public transport

services, *Availability* is added to the bottom of the figure in this study. A service can in the end only be used by persons who are able to do so.
The pyramid is divided in dissatisfiers and satisfiers. If a factor in the dissatisfier part of the pyramid is fulfilled, it will not necessarily lead to a positive experience. However, if such a factor is not fulfilled, it will lead to a negative experience. For the satisfying factors, it works the other way around. If such a factor is complied with, it will lead to a positive experience. If a satisfier is not met, it will not necessarily lead to a negative experience. From the pyramid can be concluded that all bus services should at least be safe, reliable and available. These three aspects form the base of the pyramid. Next to that, a service must have an acceptable speed and must be easy to use. This holds for BHLS as well as conventional services. The level of service can be increased by improving the level of comfort and the experience.

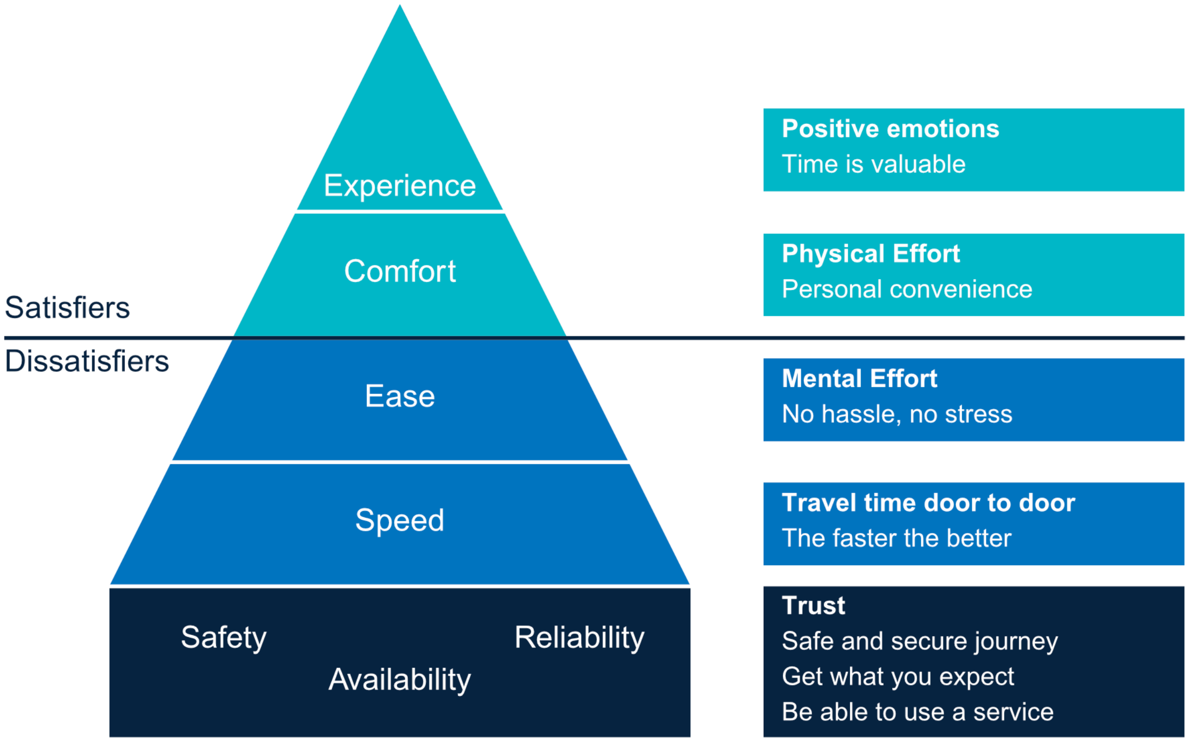

Figure 2.1 Pyramid of Customer Needs (Adapted from van Hagen, 2011)

Operational speed

The first aspect is a high operational speed which all reviewed works mention as one of the characteristics of BHLS. Finn et al. (2011) observe the implementation of BHLS has led to an improved operational speed in all their case studies. Heddebaut, et al. (2010) also observe an increased speed for the majority of their case studies, although the improvements differ substantially per case study in both works. The speed is in the lower part of the pyramid of customer needs. According to the pyramid, all bus services should have an acceptable operational speed to fulfil the customer needs, no matter whether a service is BHLS or conventional.

Reliability

The reliability is considered in all the reviewed works. A reliable service meets the expectations of the passengers (CROW, 2024). Together with safety, it forms the foundation of van Hagen’s pyramid. Therefore, all bus services should be reliable, not only the BHLS services. A service can be seen as reliable once a certain threshold with respect to on-time performance is met. What this threshold is, is case study dependent. BHLS services could excess this threshold and be *even more* reliable to distinguish themselves.

Dedicated infrastructure

BHLS often comes with its own dedicated road infrastructure (Finn, et al., 2011). However, dedicated infrastructure is not a goal in itself but a tool to achieve service-related aspects (Odijk, 2024). Bus lanes or other forms of dedicated road infrastructure are designed to reduce the number of conflicts with other traffic. A reduction of conflicts can improve the operational speed and punctuality. The presence of dedicated infrastructure cannot directly be related to one of the layers of the pyramid as it is a tool that serves multiple goals. The goals that it serves, improve speed and reliability, are in the lower part of the pyramid.

Frequency

BHLS services generally come with a high frequency. Most have a peak frequency of at least 6 buses per hour per direction (Finn, et al., 2011). In their case study analysis, Heddebaut, et al. (2010) observe that all BHLS services offered a higher frequency than the conventional service they replaced. The frequency is not directly reflected in one of the layers of the pyramid of customer needs. The frequency could influence the travel time of passengers as a higher frequency may reduce hidden waiting time (extra time people spend on their origin before they start their trip). Therefore, the frequency may relate to speed. Next to that, the frequency can relate to the ease factor. There is less need to plan a trip in advance for services with a very high frequency. In case of a very frequent service, one could simply go to the bus stop and take the first bus that will depart within at most a few minutes. Lastly, higher frequencies come with a higher capacity which reduces the in-vehicle crowding levels. This relates to the comfort aspect from the pyramid.

Identity

Many BHLS systems have an own branding which distinguishes them from conventional buses. The identity is meant to create a positive image to attract new passengers (Finn, et al., 2011). The branding of a BHLS fleet is related to the experience of the passengers which is in the top of the customer needs' pyramid. This means that it is a satisfier which BHLS services can apply to increase the level of comfort to an above standard level.

Seat availability

Eight of the reviewed works relate a high seating chance to BHLS. This is one of the aspects where BHLS differentiates itself from BRT. BHLS has a high seat availability to assure a certain level of comfort. BRT is not designed as a service with a high level of comfort but as a service that carries as many people as possible from A to B with high occupancy standards (Hidalgo & Gutiérrez, 2013). The high seat availability is related to comfort which is in the satisfiers part of the pyramid.

Stop comfort

Most reviewed works note an improved level of comfort at the bus stop for BHLS. However, there is no unambiguous answer to what a comfortable bus stop should look like. Odijk (2024) mainly discusses the facilities for first and last mile transport like good walking and cycling routes to the stop and bicycle parking facilities. Van der Scheer (2016) and Finn, et al. (2011) also mention bicycle parking facilities. Eichler (2023) suggests shelters as part of the stop design. Other works remain a bit vaguer and write about “stops with amenities” (Borsje, et al., 2023). A comfortable stop where one can park their bike and shelter for rain, wind, and sunshine falls within the upper part of the pyramid.

Dynamic traveller information

A dynamic traveller information system (hereafter DRIS – Dutch abbreviation for Dynamisch Reizigersinformatiesysteem) is a system that provides live information about the arrival and departure time to travellers. Real time information can be shared with passengers using displays in the vehicles and panels at the bus stop. It therefore also relates to the stop comfort as described above. DRIS can be seen as part of the experience aspect of the pyramid of customer needs.

Stop density

Several studies see a low stop density as an aspect of BHLS. There is a strong correlation between the stop density and the operational speed (Finn, et al., 2011). The less stops, the higher the speed. Like dedicated road infra structure, a low stop density is not a goal in itself. It is an effective measure to improve the operational speed. However, a lower stop density means that on average the access and egress times are larger which makes services less accessible. Larger access and egress times have a negative impact on the door-to-door travel times. Although it might improve the operational speed of the bus itself, it can increase the total door-to-door travel times if the network is not well designed. Next to that, large stop densities can have a negative impact on the availability of the service, especially for people that have difficulties with walking. The stop density thus relates to the speed and availability which are both in the lower half of the pyramid.

Operation hours

The last aspect considered in literature is wide operation hours. This means that a BHLS service should be available from early in the morning until late in the evening. Borsje, et al. (2023) show that wide service hours are one of the most valued aspects by travellers of high-quality buses. The operation hours relate to the availability of the service which is in the base of the pyramid.

2.3 Targets of BHLS

When explaining what BHLS is, it can be helpful to refer to the targets of BHLS instead of the ten (technical) aspects as found in the literature review. Figure 2.2 shows how the ten aspects described above can be brought back to six targets: fast, reliable, frequent, recognisable, available, and comfortable. Some of those targets are only affected by one of the aspects whilst others are affected by multiple aspects. All aspects have a positive impact on the target they relate to, except for the low stop density. This has a negative impact on the availability of the service. These are the six targets in which BHLS services distinguish themselves from conventional bus services.

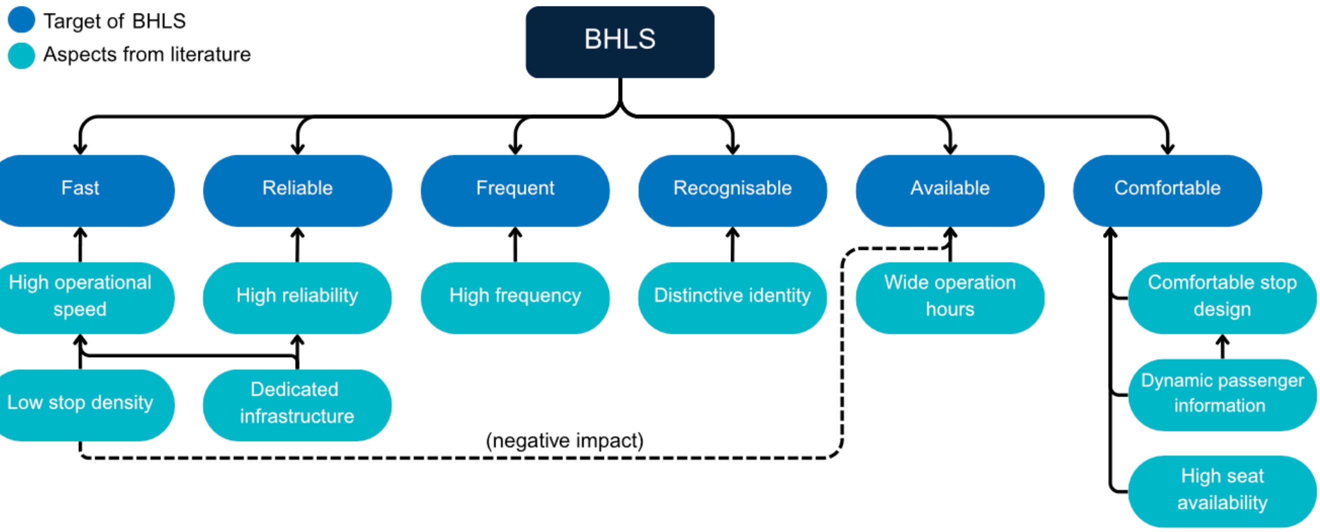

Figure 2.2 Aspects and targets of BHLS

3 Methodology

Each research question requires a different approach to come to an answer. Figure 3.1 shows a graphical representation of the resources needed per question. The first sub-question has already been answered by literature in Chapter 2. This chapter describes the strategy to answer the remaining sub-questions.

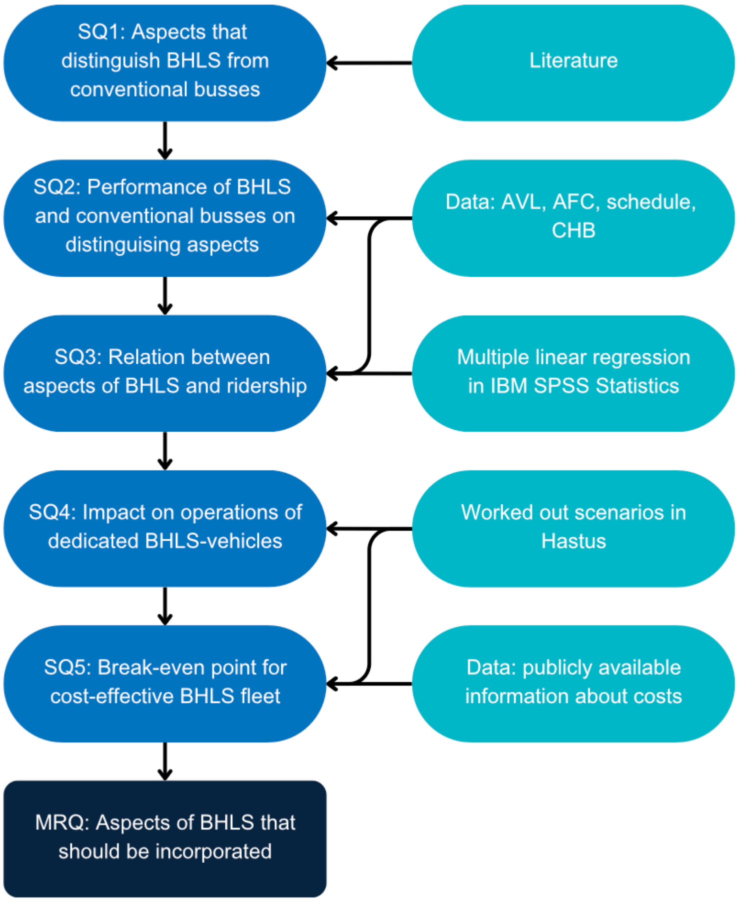

Figure 3.1 Required resources per research question

3.1 Scope of data selection

First, a selection of lines from the case study area must be made for sub-questions 2 and 3. All lines with a dedicated brand that could be considered as BHLS are included. For convenience, those services are called BHLS services in this work. The comparison in Chapter 5 should reveal whether the BHLS services comply with the aspects as found in Chapter 2. Next, conventional services are selected that serve on the same spatial scale as the BHLS services. This means that if all BHLS services in the case study area are regional buses, only the regional conventional bus services are considered. If BHLS serves on local scale as well as regional scale, local and regional conventional services are considered. On demand services, shuttle services to for example touristic attractions or theme parks, and peak hour lines that run either only in the morning or only in the evening are neglected. This choice is made because those service types are considered less comparable to BHLS services. Also, lines for which not all necessary data is available cannot be used.

Once the lines are selected, a time frame must be selected for which the data is collected. To balance the quality of the results and computational effort, a time span of one month is chosen for the analysis. The data should be as representative as possible for most users. There should be no holidays within the chosen time span because roads are generally less busy, and less people travel by bus during holidays. This may bias the performance on the BHLS characteristics. Therefore, the month November 2024 is selected. At the moment of data collection, November 2024 is the most recent month without official public holidays in the Netherlands. The time of day for which the data is collected should match the moment in time when most people use the bus. The performance on that specific moment of the day is how the largest group of passengers experiences the quality of the service. This strategy overcomes the potential situation in which unrepresentative data is collected for services that perform significantly different during peak hours compared to off-peak hours. Figure 3.2 shows the ridership distribution over the day of all EBS services in November 2024, based on automatic fare collection (AFC) data. As the morning peak is higher than the evening peak, the morning peak (7:00h – 9:00h) is used for the analysis. Later on, the analysis is repeated for the off-peak (12:0h – 14:00h) to see whether the same effects can be observed.

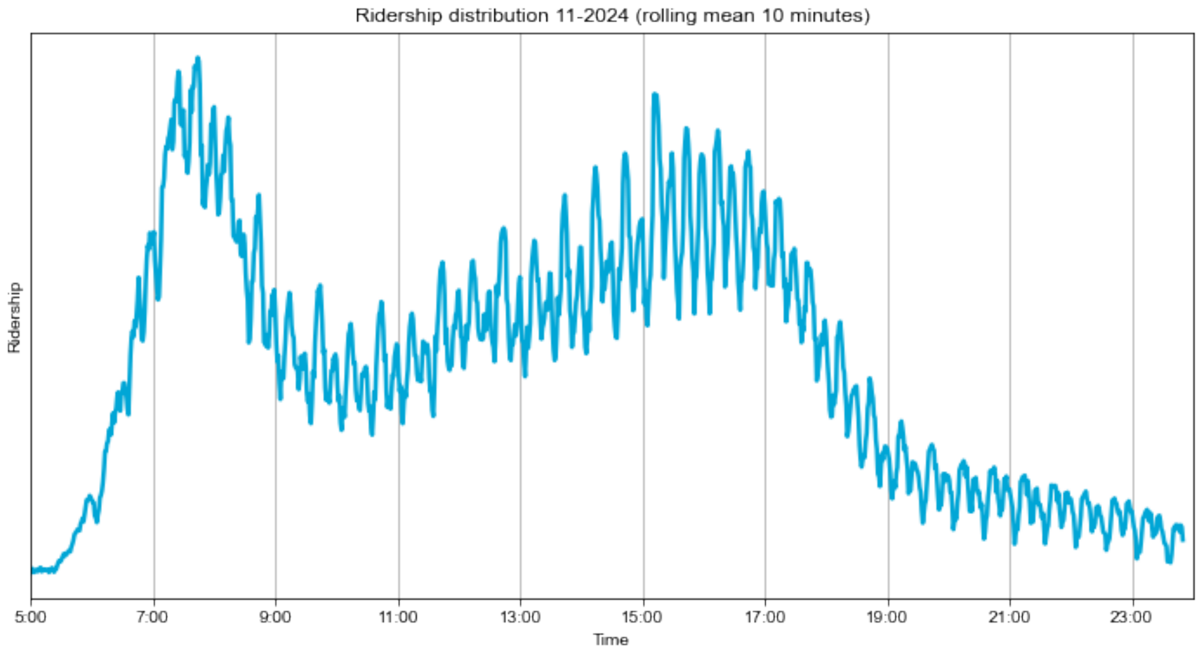

Figure 3.2 Ridership distribution over the day (source: EBS AFC data)

3.2 Comparison between BHLS and conventional buses

The aspects on which the lines are assessed flow from Chapter 2. Those are: operational speed, reliability, frequency, recognisability, availability, and comfort. For each aspect, first the average performance of each individual line is computed by collecting and filtering data from the business intelligence dashboard of EBS. The result per line is stored in a dataset. From this dataset, average performances per brand per region are computed. Each line equally contributes to the average performance per brand per region. Performances are not weighted by for example vehicle service hours because that could mask the performance of lines with short line lengths or low frequencies. Adding weight factors could therefore lead to overseeing certain effects.

The performance of the BHLS service is compared to the performance of the conventional service for each region separately. This choice was made to gain insight how different BHLS brands in different regions perform. Furthermore, a separate comparison per region avoids biased results because of regional differences. An independent samples t-test is applied to test whether the performances are significantly different. A t-test tests the hypothesis that two data sets have the same mean (Dekking, et al., 2005). If the *p*-value of the t-test is below 0.05, the hypothesis is rejected, and it can be concluded that there is a significant difference in performance. The mean performance per line is used as input for the t-test. This means that there is only one data point per line. This choice is made to avoid interdependency in the data set.

A regular independent samples t-test assumes equal variances between the two data sets (Dekking, et al., 2005). To verify whether this is true, a Levene's test is used. Levene's test is designed to test the hypothesis that two data sets have the same variance. If the *p*-value of the Levene's test is below 0.05, the hypothesis is rejected, and it can be concluded that the data sets have unequal variances. In such cases, it is not appropriate to apply a regular independent samples t-test. A Welch's test is a good alternative for the t-test (Derrick, et al., 2016). This test is conducted in case variances of the two sample groups are unequal. However, unlike an independent samples t-test, the Welch's test has limited statistical power for extremely small sample sizes ($N \leq 5$) (de Winter, 2013). Therefore, no statistical test is conducted when the variances are unequal and the sample size of at least one sample is smaller than, or equal to 5. Instead, the effect size is computed to still get an idea of the order of magnitude of the difference between conventional and BHLS services. The effect size is a measure for how far the means of two samples are apart. In this work, Cohen's *d* is used to determine the effect size. It is determined as the difference of the means of the two data sets, divided by the standard deviation of the control group, in this case the conventional services (Equation 3.1). A positive *d* means that BHLS scores higher on the considered aspect, a negative *d* means that BHLS scores lower. If the *d*-value is smaller than |0.2|, the difference between the means is considered small. For *d*-values larger than |0.8|, the difference is considered large (Bhandari, 2023).

$$d = \frac{\overline{x_1} - \overline{x_2}}{s_2} \quad \text{(Eq. 3.1)}$$

- $\overline{x_1}$: mean of the BHLS data set
- $\overline{x_2}$: mean of the conventional (control) data set
- s_2: standard deviation of the conventional (control) data set

Figure 3.3 gives an overview of the strategy to compare BHLS services to conventional bus services.

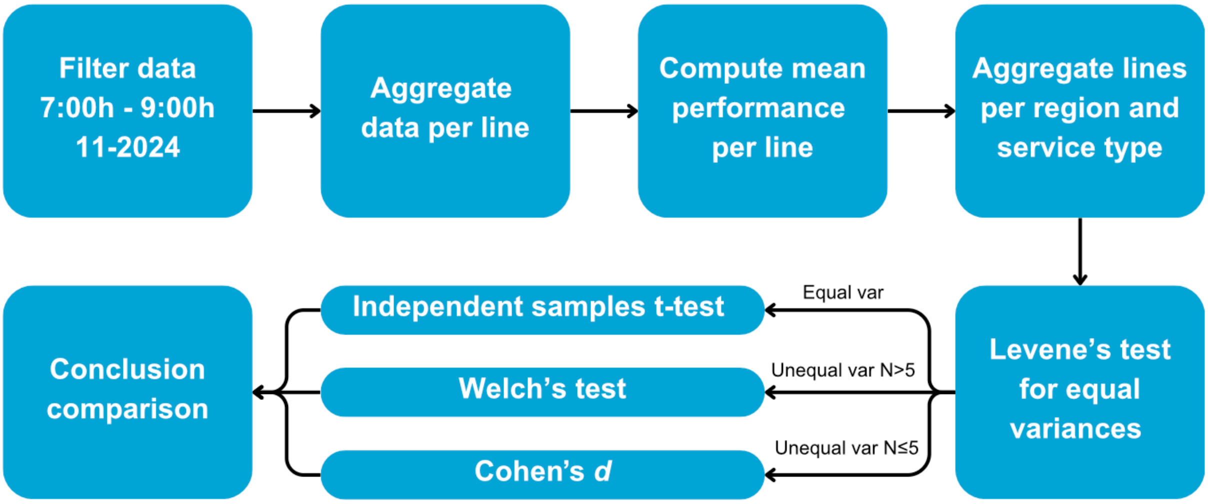

Figure 3.3 Flow chart methodology comparison

To get a more complete image of the difference between BHLS and conventional services, the analysis is repeated for an off-peak timeslot (12:00h – 14:00h). The analysis is only repeated for aspects on which performances can differ over the day: operational speed, punctuality, cancellations, and seat availability. The off-peak analysis should reveal whether differences observed during the morning peak, also exist outside the peak hours and vice-versa.

The following sub-sections explain how the performance on each of the targets is measured for the comparison. The explanation is based on the analysis for the morning peak. For the off-peak analysis, the same strategy is applied.

3.2.1 Operational speed

The timetables within the case study area are designed using Hastus. Hastus is a software package developed by Giro which can be used for designing timetables and creating crew and vehicle schedules (GIRO Inc., n.d.). The operational speed of each line for the morning peak on weekdays in November can be extracted from Hastus. The operational speed as used in this study is the scheduled average speed over the entire line. The actual speed, based on AVL data, could also be used. However, travel advice in planning apps is based on scheduled speed. Therefore, it is assumed that passengers use this speed as a reference rather than the actual speed. Furthermore, deviations from the scheduled speed will already be covered in the reliability part. The difference between the scheduled and actual speed is expected to be small. Using the actual speed instead would likely not have a large effect on the results.

Per line, the average speed of all trips is computed. All trips that departed between 7:00h and 9:00h from their departure station are included. This is needed because running times can differ over the day, even within the morning peak. The operational speed of BHLS services is expected to be higher compared to the conventional services as for example Finn, et al. (2011) and Heddebaut, et al. (2010) found in their case study analysis.

3.2.2 Reliability

A bus service is reliable once it gets passengers to their destination at the expected moment. The reliability consists of two aspects: punctuality and cancellations (CROW-KpVV, 2024). Services with a high punctuality and a low cancellation rate are considered reliable. According to the findings in the literature review (Chapter 2), BHLS should have an above standard reliability and is thus expected to have a higher punctuality and a lower cancellation rate compared to conventional bus services.
In this study, the thresholds for punctuality of the CROW-KpVV (2024) are used. Using this standardised method allows to compare the punctuality in the case study area to the national average. The punctuality as reported by the CROW-KpVV is a combination of departure and arrival punctuality. To be "on time", a trip must depart no earlier than 30 seconds before, and no later than 180 seconds after the scheduled departure time. Next to that, a trip must arrive no later than 30 seconds after the scheduled arrival time at the final destination.
In this work, only the departure punctuality at the beginning of the line and arrival punctuality at the endpoint of the line are considered. This means the punctuality of a trip can be 100, 50, or 0%. The punctuality is 100% if a trip is it meets both requirements, 50% if it meets one of the requirements, and 0% of both requirements are not met. The overall punctuality of a line is the average punctuality of all trips. Table 3.1 shows an example of punctuality for four trips of a line. For the example line, the punctuality would be (250 / 4 =) 62.5%. The punctuality is based on trip recordings (AVL data).

Table 3.1 Example punctuality data

Trip	***Departure Punctuality [s]***	***Arrival Punctuality [s]***	***Trip Punctuality [%]***
1001	-34 *s*	13 *s*	50%
1002	10 *s*	-207 *s*	100%
1003	196 *s*	42 *s*	0%
1004	-18 *s*	-3 *s*	100%

In the CROW-KpVV method, also punctuality at important network nodes is included. This is neglected in this work because collecting punctuality data at intermediate nodes takes too much computational effort. This choice can affect the results. However, the effect is expected to be small because the start and endpoint of the lines are included which together already give important information. Trips that departed and arrived on time have a high chance of also being on time at the intermediate nodes. Trips that departed and arrived with a delay were probably also delayed at the intermediate nodes.
Instead of this classical approach, also a headway-based punctuality could be calculated. In headway-based punctuality, delays or early departures are not based on the scheduled departure or arrival time but on the scheduled headway (van Oort, 2014). In this approach, it is important that buses have a consistent headway rather than that they stick to a timetable. This approach is useful for high frequent services where passengers show up at a stop without planning their exact departure time. Passengers tend to do this if the frequency is at least 6 buses per hour (van Oort, 2011). In the comparison here, also conventional services with a relatively low frequency are included. Headway-based punctuality is therefore not the most suitable method for the comparison in this work.

The cancellation of trips can be measured in several ways. One method could be to determine the percentage of trips that are cancelled. In this work, the cancellation is defined as the percentage of the scheduled kilometres that has been cancelled. This method overcomes the possible scenario in which a trip is cancelled only partially. Furthermore, it makes the cancellation of a longer trip more important than one of a shorter trip. This is relevant because in some cases not all trips run over the full line length. Though, the difference between the percentage of cancelled trips and cancelled kilometres is expected to be low. Working with the percentage of cancelled trips would therefore be a suitable alternative for cases where rate of cancelled kilometres is difficult to establish. In this case study, the percentage of cancelled kilometres per line for the desired moment in time can directly be retrieved from the business intelligence dashboard of the operator.
The results of the cancelled kilometres will be compared to the requirements from the authorities in the case study area. Since the requirements include all trips, it would not be odd if the requirements are exceeded during the (morning) peak. In case of a shortage, the effects are likely to first affect the busiest moments which are the peak hours. Higher cancellation rates during the peak can be compensated by lower off-peak cancellation rates to in the end meet the requirements.

3.2.3 Frequency

The frequencies vary over the day and are sometimes even direction depended. In this work, the number of buses per hour per direction is used. It is computed as the total number of departing buses at the beginning of the line during the two-hour timeframe in both directions divided by four. Based on example frequencies in Table 3.2, the frequency for line 455 would be 4.25 buses per hour during the morning peak. The number of departing buses per hour per direction as displayed in Table 3.2 can directly be extracted from the business intelligence dashboard of the operator. According to the findings in the literature review (Chapter 2), the frequencies of BHLS services should be higher than the frequencies of conventional services.

Table 3.2 Example frequency data

Line + direction	***Buses between 7:00h – 7:59h***	***Buses between 8:00h – 8:59h***
455 direction 1	5	4
455 direction 2	4	4

3.2.4 Recognisability

The recognisability of bus services is not as easy to quantify as other aspects. For the comparison, a qualitative description of the visual differences between the brands is provided. In this comparison, it is assessed till what extend the BHLS services are distinguishable from conventional services. Also, whether BHLS is recognisable as a high-quality service or as a service that is better than the conventional service is included in the comparison.

3.2.5 Availability

As described in Chapter 2, the availability for BHLS is determined by wide operation hours. Therefore, the availability is expressed in frequencies outside the peak hours. This is done for two timeframes: off-peak (12:00h – 14:00h) and in the evening (19:00h

– 21:00h). The off-peak timeframe is chosen such that is in between the two broad peak moments of the day. The evening timeframe is selected for a moment after typical Dutch dinner time when ridership is low (see Figure 3.2). The same methodology for the determining of the frequencies is used as for the peak-hour frequencies. The BHLS frequencies outside the peak hours are expected to be higher compared to conventional services.

The availability because of wide exploitation hours could also be indicated in alternative ways. Of course, other timeframes could be selected with the current methodology. This could lead to different numerical results, but the same effects are likely to be observed in the comparison. Alternatively, the availability could be indicated as the number of hours between the first trip and the last trip from the timetable. Although this method would arguably give a better indication of the span of the operation hours, it does not give much information how good the availability of a service is. For example, a service that runs from 5:00h till 23:30h has quite a wide span of exploitation hours. However, if the second-to-last bus runs at 21:30h already, the service is arguably less availably than a service that runs till 23:00h with a high frequency. For this reason, the methodology which uses the frequency outside the peak hours is used.

3.2.6 Comfort

Three aspects are considered for the comfort of the bus service: the stop design, presence of dynamic travel information, and seat availability. The comfort aspects are based on findings in the literature review. Since all considered bus services in the case study area have an in-vehicle DRIS, only the presence of a DRIS panel at the bus stop is studied. With that, the presence of dynamic traveller information becomes part of the stop design.

Stop design

For the stop design, three aspects are considered: the presence of a shelter, bicycle parking facilities, and a DRIS panel. These aspects flow from the reviewed literature (Chapter 2). Shelters could have a positive effect on the perceived level of comfort at bus stops. They provide shade on sunny days and protect passengers against wind and rain. Especially the latter could be of great value in the Netherlands where it rains 192 days a year on average (KNMI, 2022). Next to that, shelters often come with a bench which is often used by elderly (Bins Ely, et al., 2012). Bicycle parking facilities is mentioned multiple times as part of a comfortable stop in the reviewed works from Chapter 2. It makes it more convenient to use the bus for people that live further away from the bus stop. DRIS panels have proven to have a positive impact on the perceived waiting time. A case study in The Hague (NL) shows a reduction in perceived travel time of 20 percent (Dziekan & Vermeulen, 2006).

Data on the facilities at Dutch bus stops is recorded in the Centraal Halte Bestand (hereafter CHB) (NDOV, 2025). With a python script, the data from the CHB is coupled to a list with all the stops of each considered line using the quay code. The quay code is a unique code for each platform of a bus stop. Most bus stops have at least two platforms: one for each direction. This means that one bus stop can have multiple quay codes. The CHB is coupled to the list of stops using the quay code instead of the stop name to overcome the situation in which the different platforms at a bus stop have different properties. An example of this can be seen at the stop Kapelweg in the snip-it from the CHB in Figure 3.4. One platform has a shelter, but the other one does not. The shelter and the passenger information displays are quay dependent as it is assumed that people wait on the platform from which their bus will depart, and a DRIS panel usually is platform specific. Bicycle parking facilities are stop dependent instead of platform dependent as passengers do not necessarily park their bikes at their departure platform. Therefore, the python code is slightly modified such that a stop is assessed to have a bicycle parking facility if at least one of the quays has a bicycle parking facility.

	A	B	C	E	G	H
1	ns1:publicname	ns1:town	ns1:quaycode	ns1:shelter	ns1:passengerinformationdisplay	ns1:bicycleparking
2	Leie	Assen	NL:Q:15005330	ONWAAR	ONWAAR	ONWAAR
3	Kapelweg	Eersel	NL:Q:64310190	WAAR	ONWAAR	WAAR
4	Kapelweg	Eersel	NL:Q:64310200	ONWAAR	ONWAAR	ONWAAR
5	Hidaard	Hidaard	NL:Q:20630310	ONWAAR	ONWAAR	ONWAAR
6	Hidaard	Hidaard	NL:Q:20630300	ONWAAR	ONWAAR	ONWAAR
7	Floriande Zuid	Hoofddorp	NL:Q:56230100	WAAR	WAAR	ONWAAR
8	Floriande Zuid	Hoofddorp	NL:Q:56230630	WAAR	WAAR	ONWAAR
9	Casino	Knokke	BE:Q:79640040	ONWAAR	ONWAAR	ONWAAR
10	Frankrijkstraat	Lent	NL:Q:61191400	WAAR	ONWAAR	ONWAAR
11	Frankrijkstraat	Lent	NL:Q:61191390	WAAR	ONWAAR	ONWAAR
12	Homerilaan	Midwolda	NL:Q:13121110	ONWAAR	ONWAAR	ONWAAR
13	Homerilaan	Midwolda	NL:Q:13121120	ONWAAR	ONWAAR	ONWAAR

Figure 3.4 Section from Centraal Halte Bestand

In one of the regions in the case study area (Haaglanden Streek, see Chapter 4), the codes for quays used internally at EBS do not correspond with the CHB. Therefore, the data from the CHB is coupled to the list of stops per line manually, based on stop name ('publicname'). Some stops have multiple platforms with different properties (like in the Kapelweg example). In such cases the Halteviewer tool from DOVA is used to retrieve the correct platform (DOVA, 2025). If the properties of different platforms at a stop are not the same and the platform cannot be retrieved from the Halteviewer, the stop is not included in the dataset.

The results of these analyses are percentages of stops with a shelter, bicycle parking facility, and DRIS panel per line. Percentages are used because the absolute numbers are depended on the line length in terms of stops. The percentages are computed for the full line length, also if a part of the trips short turn at an intermediate stop. Correcting the percentage for short turning services would take a lot of computational effort while the percentages are expected to remain roughly the same. For the shelters and the dynamic passenger information panels, these percentages are the average of both directions. Based on the example data for line 455 from Table 3.3, the shelter percentage would be (37 + 37) / (41 + 41) = 90.24% and the DRIS panel percentage would be (31 + 30) / (41 + 41) = 74.39%. The bicycle parking percentage is not direction depended as this is determined per stop instead of per platform. The percentages on those tree aspects are expected to be higher for BHLS services compared to conventional services.

Table 3.3 Example stop property data

Line + direction	*Stops with shelter*	*Stops with passenger information display*	*Total number of stops*
455 direction 1	37	31	41
455 direction 2	37	30	41

Seat availability

The seat availability is based on the number of passengers in the bus and the seating capacity of the bus. First, the number of passengers of each trip at each stop is retrieved for the morning peak (7:00h – 9:00h) on working days in November 2024. This information is based on AFC data. Then, the number of passengers is divided by the seating capacity of the vehicle that is deployed on that trip. This results in an occupation dataset that includes all lines, all trips within the set timeframe, and all stops. Based on this information, the seat availability can be derived. The seat availability is computed for two levels: all passengers can sit, and all passengers can sit without someone sitting next to them. If the occupation is less or equal to the seat capacity, all passengers can take a seat. If the occupation exceeds the seat capacity, at least one passenger needs to stand. An occupation of 50 percent of the seat capacity or less means that all passengers could sit without someone next to them, assuming rows of two chairs all over the bus. This level of crowding is included because crowding levels over 50 percent can already have a negative influence on the perceived travel time (Yap, et al., 2023).
On smaller sections, having to stand might not lead to very negative experiences. However, standing for longer periods should be avoided. Therefore, a trip is considered to comply with the level where all passengers can sit (without someone next to them) if this is true on at least 90 percent of the line, measured in stops. Using this percentage avoids local effects from disturbing the results. The requirement documents from the case study area all prescribe that the seat capacity may not be exceeded for more than a certain amount of time which varies per region (MRDH, n.d.; Provincie Flevoland, Provincie Gelderland, & Provincie Overijssel, 2021; Vervoerregio Amsterdam, 2021). In this work, a percentage of the line length in stops is used because the occupancy is already calculated per stop. This, in combination with the fact that running times may vary per trip makes that using the number of stops is less complex compared to using time. The choice of 90 percent of the stops is expected to result in similar results with the strictest maximum time passengers should stand from the requirement documents. A strict requirement is chosen such that buses are relatively easily classified as crowded. This results in more variability in the results which can better reveal differences between conventional and BHLS services.
The results are two percentages. The first is the percentage of trips on which all people could take a seat on at least 90 percent of the line. The second is a percentage of trips on which all people could sit without someone next to them on at least 90 percent of the line.

3.3 Relation BHLS aspects and Ridership

In this section, a model will be selected to investigate the relation between the aspects of BHLS and ridership. This section also discusses the input variables for the model and the model development and validation strategy. There will be two models developed, one for the morning peak (7:00h – 9:00h) and one for the off-peak (12:00h – 14:00h).

3.3.1 Model choice

There are multiple possible methodologies to investigate the relation between the aspects of BHLS and ridership. The first option is Structural Equation Modelling (SEM). SEM allows to investigate relations between observed and unobserved (latent) variables (Byrne, 2010). Adding unobserved variables can be seen as adding an extra layer to the model. Instead of directly investigating the relation between for example punctuality and ridership, the relation between punctuality and reliability and the relation reliability and ridership is estimated. The ability to add unobservable latent variables can make the model quite complex since a lot of extra relations need to be estimated. The disadvantage of a complex model is that it requires a large sample size. There are several rules of thumb including a minimum of 200 (Schumaker & Lomax, 2010) or at least 10 observations per indicator (Elangovan & Rajendran, 2015). These number of sample sizes are not in reach within the network of EBS. Working with a small sample size can lead to insignificant estimations and a high root mean squared error of approximation (Byrne, 2010). Therefore, SEM is not a good methodology for this specific research.

An alternative methodology is multiple linear regression. It is a model which predicts the value of a dependent variable based on multiple independent variables (also called predictors) (Eberly, 2007). In this work, the dependent variable is ridership, and the independent variables are the aspects of BHLS. Unlike SEM, multiple linear regression cannot estimate the contribution of unobserved variables – like reliability – to ridership. However, the model is capable of estimating the relation of the observed variables that are behind the reliability (punctuality and cancelled kilometres) to ridership. The estimated relation of only the observed variables to ridership should give enough information to answer the main research question. Eberly (2007) suggest that for multiple linear regression, the sample size should be at least $p + 10$, but preferably $p + 40$, where p is the number of predictors. Since this sample size requirement can be met within the case study area, the multiple linear regression method is selected to investigate the relation between the aspects of BHLS and ridership.

3.3.2 Input variables

The dependent variable is ridership. This is defined as the total number of boarding passengers between 7:00h – 9:00h (or 12:00h – 14:00h) in November 2024.

The predictor variables for the multiple regression analysis are the aspects of BHLS as described in Section 3.2. The seat availability is not included in the model as it is computed based on ridership. Including the seat availability could bias the results. In SEM, including the seat availability is less likely to disturb the outcome if a latent variable (e.g. comfort) is positioned between the seat availability and ridership.

To make the model more accurate, external factors could be included. Especially the population and job density could have a significant impact on ridership as they determine the potential for bus transit (Taylor & Fink, 2003). To properly include this, the densities should be collected at a very high resolution as access and egress distances are relatively small for bus transit (van der Blij, et al., 2010). Gathering this data takes a lot of computational effort on the scale of this work. Therefore, the densities are not included in the model. It is expected that this choice does not largely affect results. An advantage of not including the densities or other external factors is that the number of data points per predictor variable stays limited which reduces the risk of overfitting.

Longer lines naturally can have more boarding passengers than shorter lines. Different line lengths could therefore also lead to biased results. To avoid this, the number of stops will be added as one of the predictor variables. Since the number of stops can be different for both directions of a line, the number of stops of a round trip is chosen to be the predictor variable. For example, if a line has 23 stops in direction 1 and 26 stops in direction 2, the number of stops that will be used as input for the model is 49. Also the length in kilometres could have been chosen as additional predictor variable to avoid biased results because of the line length. The number of stops is chosen because this gives a better representation of the opportunities for passengers to board. An overview of the aspects and their units is presented in Table 3.4.

Table 3.4 Input variables for regression model

Aspect	*Unit*
Scheduled operational speed	km/h
Punctuality	%
Cancelled kilometres	%
Frequency between 07:00 – 09:00h	buses per hour per direction
Frequency between 12:00 – 14:00h	buses per hour per direction
Frequency between 19:00 – 21:00h	buses per hour per direction
BHLS service	1 = yes; 0 = no
BHLS vehicles deployed on BHLS lines	%
Stops with a shelter	%
Stops with bicycle parking facility	%
Stops with DRIS panel	%
Number of stops (bi-directional)	number of stops

An important assumption of multiple linear regression is that predictors should not be highly correlated with each other (Eberly, 2007). To test this, a Pearson correlation matrix is computed using IBM SPSS Statistics (IBM, n.d.). A correlation |0.7| or higher is considered high (Tranmer, et al., 2020). When there are pairs with a high correlation, only one of the variables can enter the model. The decision of which of the variables is used for the model is made by testing both variables and comparing the coefficient of determination (R^2).

3.3.3 Model development

Multiple linear regression is used to estimate the contribution of BHLS aspects to ridership. This is done by determining a regression coefficient for all aspects that have a significant contribution. The final model with p significant predictors will be in the form of Equation 3.2. The model will be developed in IBM SPSS Statistics (IBM, n.d.). The regression coefficients are estimated using ordinary least squares (Eberly, 2007).

$$y = \beta_0 + \beta_1 * x_1 + \beta_2 * x_2 + \cdots + \beta_p * x_p + \epsilon \quad \text{(Eq. 3.2)}$$

- y: ridership
- β_i: regression coefficients
- x_i: aspects of BHLS (predictors)
- ϵ: error term

The predictors will be added using the forward selection method. With this approach, the predictor variables will be added step by step. The variable with the highest correlation (either positive or negative) with ridership will be added first (IBM, n.d.). After that, variables will be added by order of highest partial correlation. The addition the variable with the highest partial correlation leads to the largest possible improvement of the coefficient of determination (R^2). A variable will only be added if it improves the model. To test the model improvement, an F-test is performed. The significance of the F-test must be below 0.05 for a variable to enter the model (Tranmer, et al., 2020).
Another way of building the model would be the backward elimination approach (IBM, n.d.). In this approach, all variables are added to the model in the first step and then insignificant variables are removed one by one.

More data points per predictor gives more reliable results. In this research, the sample size is relatively low compared to the number of predictors. Therefore, in this work, it is more appropriate to scale the model up by adding variables (forward selection) instead of scaling the model down by removing factors (backward elimination).
The data set for this research contains data from three regions (Zaanstreek-Waterland, MRDH, and IJssel-Vecht). For some aspects, there might be significant regional differences in performance on the BHLS aspects which may bias the outcome of the regression analysis. For aspects where this is the case, categorical indicator variables are added to the equation so regression coefficients can be estimated for the different areas individually (Eberly, 2007). Instead of one regression coefficient for such aspects, a regression coefficient per region will be included. An example of what this looks for speed is shown in Equation 3.3. A model with regression coefficients for the different regions will be built next to a model with a single regression coefficient per aspect. The model with the highest R^2 will be selected as the final model. If this model has an R^2 above 0.7, the model is considered to be satisfactory (Lanzafame, van Woudenberg, & Verhagen, 2024).

$$y = \cdots + \beta_{speed,1} * x_{speed} * X_1 + \beta_{speed,2} * x_{speed} * X_2 + \beta_{speed,3} * x_{speed} * X_3 + \cdots \quad \text{(Eq. 3.3)}$$

- y: ridership
- $\beta_{speed,j}$: regression coefficients for speed in area j
- x_{speed}: speed in km/h
- X_j: indicator variable whether ridership is predicted for area j {1,0}

To test whether there are regional differences, a one-way ANOVA is carried out to test whether mean performance in the different areas is the same ($\mu_{ZaWa} = \mu_{MRDH} = \mu_{IJV}$) (Bevans, 2023). If the *p*-value of the ANOVA is below 0.05, it can be concluded that the mean performance is not the same in all areas. This does not necessarily require all means to be unequal ($\mu_{ZaWa} \neq \mu_{MRDH} \neq \mu_{IJV}$). For example, the means in two regions can be equal while the mean of the third is different ($\mu_{ZaWa} = \mu_{MRDH} \neq \mu_{IJV}$). Since Zaanstreek-Waterland and MRDH are in the densely populated Randstad area and IJssel-Vecht is more in the rural part of the Netherlands (CBS, 2024), it is likely that a situation exists where the performance in Zaanstreek-Waterland and MRDH is equal and the performance in IJssel-Vecht is different. Therefore, if the ANOVA shows that the means are not equal, an independent samples t-test or Welch's test is performed (see lower part of Figure 3.3) to test whether the areas MRDH and Zaanstreek-Waterland have statistically different means. If the mean performances in MRDH and Zaanstreek-Waterland are not statistically different, there will be no separate regression coefficients estimated for those regions but a single Randstad regression coefficient ($\beta_{i,Randstad}$). This is favourable since the number of regression coefficients is preferably as low as possible regarding the relatively small sample size.

3.3.4 Model Validation

To test the stability of the model, the model is validated. This is done by re-estimating the regression coefficients as found in the model development based only 80% of the dataset. The result is then used to estimate ridership on the remaining 20% of the dataset. This is repeated five times with randomly selected 80-20 distributions. This method is also known as Monte Carlo cross validation (Xu & Liang, 2001). In this work, quite a high share of data is used for the re-estimation of the coefficients. This choice

was made because the data set is relatively small compared to the number of predictors. Generally, for larger data sets, a smaller share of the data is needed for the re-estimation of the coefficients. The resulting regression coefficients for the five random seeds should not have large deviations from the originally estimated coefficients. For the estimation of ridership on the remaining 20% of the dataset, the large deviations in the root mean squared error (RMSE) should be observed.
Figure 3.5 shows an overview of the methodology to investigate the relation between BHLS aspects and ridership.

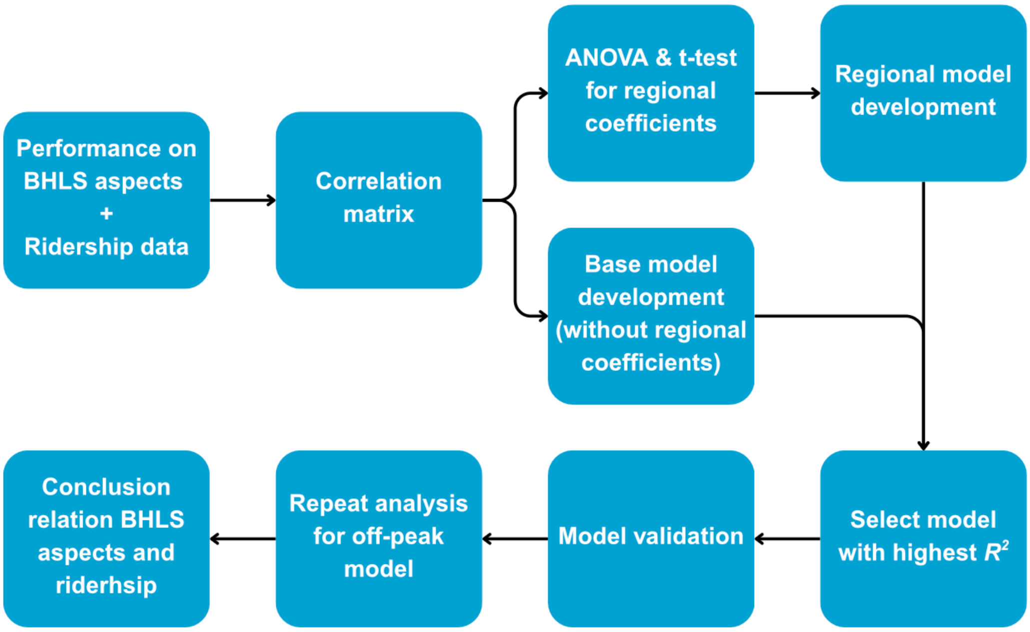

Figure 3.5 Flow chart methodology relation BHLS aspects and ridership

3.4 Dedicated BHLS fleet

One of the BHLS aspects according to literature is a dedicated BHLS branding. Buses with a BHLS livery should not be deployed on conventional lines, which may impact the operations. In this section, a methodology to assess the impact of a dedicated BHLS fleet is worked out. First, the impact on the operations is considered. After that, a framework is developed to estimate the costs of a dedicated BHLS fleet and how that should compare to ridership gains to become cost-effective.

3.4.1 Impact on operations

In the case study area, vehicle schedules are designed using software package Hastus (see Section 3.2.1). The vehicle schedules are developed in sets for one or a few depots and not necessarily for an entire concession at once. The software package takes the timetable as input and automatically computes vehicle schedules. For the automatic generation of feasible vehicle schedules, constraints are set up. Those constraints are for example that electric buses should charge for a certain amount of time after a certain number of kilometres. The deployment of the correct vehicle type on the right lines is also defined in such a constraint.
To investigate the impact of a dedicated BHLS fleet on the operations, two scenarios are worked out for sets of vehicle schedules. In the first scenario, the default set of constraints is used for the development of the vehicle schedule. In this scenario, BHLS

lines must be carried out by dedicated BHLS vehicles. In the second scenario, the constraint which tells that BHLS services must be carried out by BHLS vehicles is dropped such that all buses can be used on all lines. All other constraints remain the same.
The output indicators are the number of vehicles needed to run the timetable, the in-service time of the vehicles, and the total time of the vehicles including deadheading and turnaround times. Based on the latter two indicators, the vehicle efficiency can be computed. In this work, the efficiency is defined as the in-service time divided by the total time. It expresses how much percent of the time the vehicles are available for passengers. The indicators are computed for one weekday. A weekday is chosen because that is the normative timetable for the number of vehicles needed. Putting the results of the two scenarios side-to-side reveals what the impact on the operations is for the specific case the scenarios are developed for.
The two scenarios will be applied to two sets of vehicle schedules. Ideally, more sets with vehicle schedules are computed to get a view on the range of the impact of a dedicated fleet on the operations. However, the development of a set of vehicle schedules takes a lot of computational effort and requires a scheduling expert whose availability is limited.
The first set of vehicle schedules used is a continuation on existing work that has been done for another purpose. Some pre-work was already done for this set which saved a lot of time for the development of the two scenarios. The second set of vehicle schedules is selected in such a way that it is substantially different from the first set. This potentially leads to different results which can help getting a first indication of the range of impact on the operations of a dedicated fleet.

3.4.2 Cost-effective BHLS fleet

In this sub-section, a framework which calculates the break-even point of a cost-effective BHLS fleet is developed. Its aim is to estimate the costs of a dedicated BHLS fleet and how that should compare to a ridership increase. The framework is applied to the case study area in Chapter 7. The results from the impact on the operations as described above and publicly available information about the costs of extra vehicles and vehicle hours are used as input for the application of the framework.
What the framework looks like depends on the objective of the operator or authority. Here, it is assumed that the objective is to maximise financial profit which is a reasonable assumption for privately owned bus operating companies. This means the financial benefits in terms of increased ridership should compensate for the extra costs of a dedicated fleet. Another objective could be to maximise societal profit which would be a more reasonable objective for a transit authority. In case of societal profit, also social and environmental factors should be considered. Authorities that want to apply this framework to compute a break-even point societal profit can add social and environmental factors in line with their ambitions to the equations proposed in this section.
Based on a regression coefficient as will be determined in Chapter 6, no exact number of extra passengers due to the recognisability of BHLS can be derived. The regression coefficients only give an indication of the strength of the relation with ridership. This means that the exact financial benefits cannot be computed. However, it is possible to estimate the costs of a dedicated fleet and then compute how large the ridership gain should be to make profit. Based on the regression results, it can be determined whether this ridership gain is realistic or not.

The costs considered in the estimation are the ones related to the extra buses and the costs related to the extra vehicle kilometres/time. The extra vehicle kilometres are only related to extra deadheading because the number of in-service kilometres remains the same. Extra kilometres are therefore always out-of-service kilometres. The formula to estimate the yearly costs of a dedicated BHLS fleet can be found in Equation 3.4.

$$C = D * V + O * K + L * T \quad (\text{Eq. } 3.4)$$

- C: Additional costs of a dedicated BHLS fleet [€/year]
- D: Depreciation of the extra vehicle(s) [€/year/bus]
- V: Extra vehicles needed [number of buses]
- O: Vehicle operation costs [€/km]
- K: Extra vehicle operation kilometres [km/year]
- L: Labour costs [€/hour]
- T: Extra vehicle operation time (excluding turnaround time) [hours/year]

In this equation, potential costs for extra space for additional vehicles at the depots is neglected because the relative increase of the number of buses is likely to be small. In case the extra vehicles are electric, also some additional relatively expensive charging infrastructure could be needed. This is neglected in Equation 3.4 because the number of timetable kilometres stays the same in the two scenarios and thus the needed amount of electricity is estimated to be about the same.
Now that an equation for the costs has been set up, the ridership gains that should be realised to reach a financial break-even point can be computed. The formula to estimate this can be found in Equation 3.5.

$$R = \frac{C}{I} \quad (\text{Eq. } 3.5)$$

- R: Ridership increase to reach break-even point [number of trips/year]
- C: Additional costs of a dedicated BHLS fleet [€/year]
- I: Average income per trip on a BHLS line [€/trip]

The resulting ridership from Equation 3.5 is the minimum number of trips that should be made extra for the dedicated fleet to be financially profitable. The income per trip is in the first place based on the fares. If the break-even point estimation is estimated from an operators' perspective, potential subsidies per passenger kilometre can be included in the income as well. The income per trip is specifically for the trips made on BHLS lines since those are the lines where ridership gains are expected. The average income per trip on BHLS lines can be higher compared to conventional lines if an BHLS supplement is charged to the passengers as Arriva for example did in their former concession Zuid-Holland Noord (Arriva, 2023).
An overview of the methodology to estimate the ridership gains required to make a dedicated BHLS fleet cost-effective can be found in Figure 3.6.

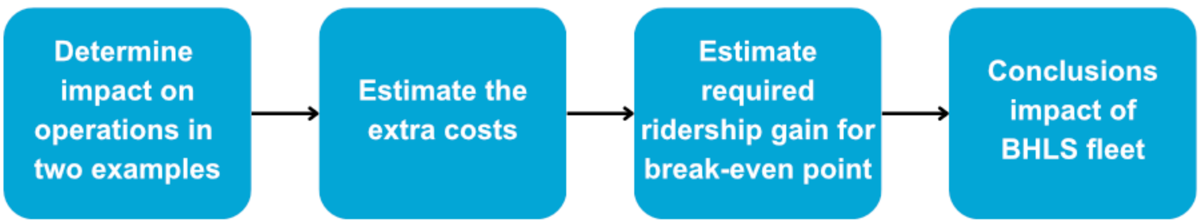

Figure 3.6 Flow chart methodology break-even point for BHLS fleet

4 Case-study introduction

The case study area consists of the network of bus operating company EBS. The operator is active in four concession areas in the Netherlands: Zaanstreek-Waterland, Voorne-Putten & Rozenburg, Haaglanden Streek, and IJssel-Vecht. The concession area Zaanstreek-Waterland falls under the authority of the Vervoerregio Amsterdam (VRA). Voorne-Putten & Rozenburg and Haaglanden Streek both fall under the authority of the Metropolitan Region Rotterdam The Hague (MRDH). IJssel-Vecht is a concession with three authorities: the provinces of Flevoland, Gelderland, and Overijssel. The concession areas are indicated in Figure 4.1 (map based on information from CROW-KpVV, 2025). A detailed overview of the networks in the four areas can be found in Appendix A.

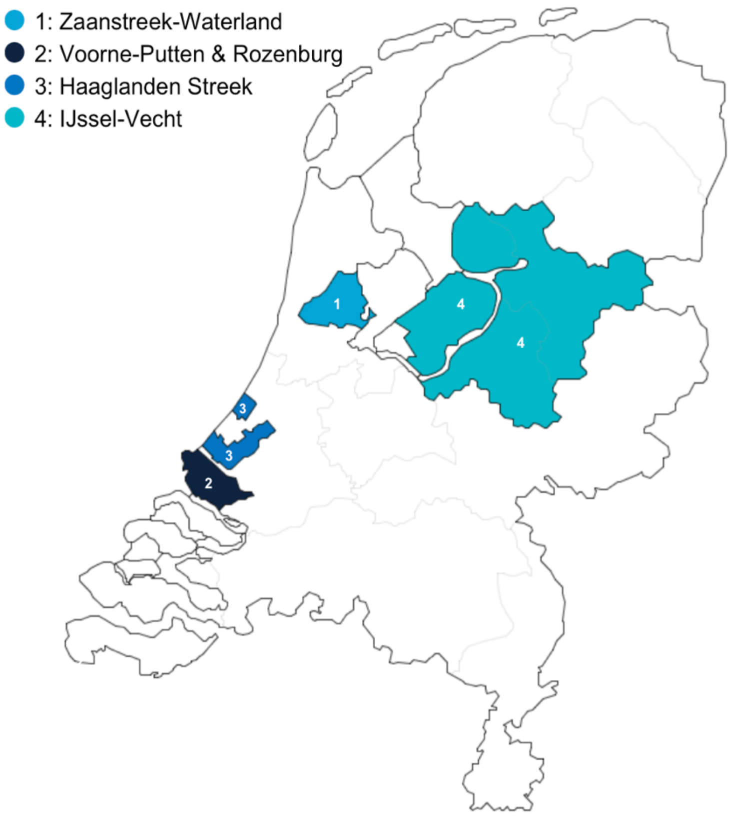

Figure 4.1 Concession areas of EBS

An overview of the type of services per line in November 2024 is shown in Table 4.1 (OV in Nederland Wiki, 2025). In this overview, BHLS lines are the lines that are deployed under a brand name which is associated with (some of) the aspects of BHLS as described in Chapter 2. Regional lines are lines that connect larger cities or towns with each other. The city lines operate (mostly) within the boundaries of a city or town. Peak hour lines operate only during one small part of the day, either during the morning peak or during the evening peak. Next to those service types, there is a category ‘other’. Within that category fall flex and on-demand services, services that replace other services during weekends or in the evening, school buses and shuttle services to touristic attractions, the flower auction FloraHolland, and theme parks Walibi Holland and Duinrell.

Table 4.1 Service types of EBS per concession area (OV in Nederland Wiki, 2025)

Concession area	*BHLS lines*	*Regional lines*	*City lines*	*Peak hour lines*	*Other*
Zaanstreek-Waterland	11	12	2	4	16
Voorne-Putten Rozenburg	2	3	3	4	4
Haaglanden Streek	2	10	8	1	7
IJssel-Vecht	10	24	47	0	72
Total	*25*	*49*	*60*	*9*	*99*

4.1 Conventional services

EBS uses three different brandings for conventional buses that serve on regional lines, city lines, and peak hour lines. In Zaanstreek-Waterland, the conventional buses carry an *M.net* branding. These buses have a grey-blue colour scheme (Figure 4.2). For this service, 12.2 or 13.5-metre-long electric buses from VDL are used as standard.

Figure 4.2 M.net bus in Amsterdam

In MRDH, conventional buses have an *EBS* branding. The buses have a white-red colour scheme with grey accents. In Voorne-Putten & Rozenburg, 12-metre-long gas-powered Iveco buses are deployed on the regional conventional lines by default (see Figure 4.3). In Haaglanden Streek, the regional *EBS* services are by default carried out by 12 or 18-metre-long gas-powered Mercedes buses (see Figure 4.4).

Figure 4.3 EBS bus in Brielle (Iveco)

Figure 4.4 EBS bus in Delft (Mercedes)

The conventional buses in IJssel-Vecht are branded as *RRReis*. The default vehicle type for the regional *RRReis* services is a 12-metre-long electric bus from manufacturer BYD. The buses are white with some green, blue, and purple accents (Figure 4.5). In some parts of the concession, older diesel-powered VDL buses are used with a different look. Those buses are completely red but are also clearly branded as *RRReis* (Figure 4.6). The deployment of those buses is temporarily until there are enough electric buses and charging facilities to run a full zero emission fleet.

Figure 4.5 RRReis bus in Zwolle

Figure 4.6 RRReis bus in Lelystad (deployed on a snelRRReis line)

All the default vehicles used for the conventional services have a low entry which makes them accessible for people with reduced mobility. Next to that, all buses (except for the temporary VDL buses) have charging points.

4.2 BHLS services

EBS also uses three different BHLS brands. Those brands are *R-net*, *comfortRRReis*, and *snelRRReis*. *R-net* buses have a recognizable red-grey look (Figure 1.1) and can be found in large parts of the Randstad region. Also other bus operators in the Randstad region make use of the *R-net* branding on BHLS lines. At EBS, the brand is used in Zaanstreek-Waterland and MRDH. According to the brand standard, *R-net* is reliable, frequent, accessible, fast, and attractive (R-net, 2023). The transit authority can quantify these aspects in their program of requirements for the concessions. As *R-net* is used in a large region with multiple authorities, the requirements for *R-net* lines may slightly differ per concession area. For example, the minimum required frequency of *R-net* services on Sundays in Zaanstreek-Waterland is 2 buses per hour (Vervoerregio Amsterdam, 2021), whereas the minimum required frequency on Sundays in MRDH is 4 buses per hour (MRDH, n.d.).
In Zaanstreek-Waterland, by default 13.5-metre-long electric buses from VDL are used for the *R-net* services. Next to the different colour scheme, the buses have seats with (artificial) leather upholstery instead of fabric. Other than that, the buses are identical. In Voorne-Putten & Rozenburg, *R-net* services are carried out by 12-metre-long Iveco buses and 15-metre-long Scania buses, both gas-powered. The Iveco buses are, apart from the colour scheme, the same as the conventional buses. With their individual air conditioning the Scania buses are a bit more luxurious compared to the (conventional) Iveco buses. In Haaglanden Streek, 12 or 18-metre-long gas-powered Mercedes buses are used by default on the *R-net* lines. These buses do not have any other features than the Mercedes buses used for conventional services.

In IJssel-Vecht, *comfortRRReis* and *snelRRReis* are used as BHLS brands. The *comfortRRReis* vehicles are 13.2-metre-long and have a distinctive white-purple-green look (Figure 4.7). As extra comfort features over the conventional buses, the vehicles have individual air conditioning, reading lights, a phone holder and a small tray table. *ComfortRRReis* claims to be fast because of its low stop density (RRReis (1), n.d.). Next to that, the service is comfortable and always available during exploitation hours. On *snelRRReis* lines, the same vehicles are used as on the conventional lines. There is only one slight difference which is the word ‘snel’ (fast in Dutch) on the front, side, and the back of the bus (Figure 4.8). The interior of *RRReis* and *snelRRReis* is the exact same. According to the brand guide, *snelRRReis* should have the same characteristics as *comfortRRReis* apart from the availability aspect. *SnelRRReis* is not 100 percent available during exploitation hours. Some services do not run around lunch time or in the (late) evening.

Figure 4.7 comfortRRReis in Zwolle

Figure 4.8 snelRRReis in Zwolle

5 Performance of BHLS

The BHLS lines in the case study area all serve on a regional scale. This can be verified from the network maps in Appendix A. Therefore, only regional conventional bus lines will be considered as reference material for the comparison between BHLS lines and conventional lines. City lines, peak hour lines, and lines categorised as ‘other’ in Chapter 4 are not included for the analysis as already explained in the methodology (Chapter 3). An overview of the number of considered lines per brand can be found in Table 5.1.

Table 5.1 Number of considered lines per brand

Concession area	*R-net*	*snelRRReis*	*comfortRRReis*	*EBS*	*M.net*	*RRReis*
Zaanstreek-Waterland	11	0	0	0	12	0
Voorne-Putten Rozenburg	2	0	0	3	0	0
Haaglanden Streek	2	0	0	10	0	0
IJssel-Vecht	0	8	3*	0	0	24
Total	*15*	*8*	*3*	*13*	*12*	*24*

*In this work, line 301 is cut into 301a from Dedemsvaart to Zwolle and 301b from Zwolle to Nunspeet as they are operated as two separate lines. This makes the number of *comfortRRReis* services 3 instead of 2.

In each of the sections in this chapter, a comparison is made between the performance of conventional services and BHLS services. The performance during the morning peak is graphically displayed per brand per area. For some aspects, the performance is different off-peak. Figures for off-peak comparisons can be found in Appendix B. This appendix also contains the descriptive statistics behind the comparison figures and tables with the statistical test results.

The concession areas Voorne-Putten & Rozenburg and Haaglanden Streek are grouped as MRDH because of the limited number of lines in those areas. The grouping is justifiable because the two areas fall under the same transit authority, MRDH. The authority sets the same general requirements for both concession areas (MRDH, n.d.). Furthermore, the same brands, *EBS* and *R-net,* are used in those two areas.

5.1 Operational speed

One of the characteristics of BHLS which is mentioned in all reviewed works in Chapter 2 is a high operational speed. Figure 5.1 shows the scheduled operational speed in the morning peak of November 2024 per brand per region. The Dutch national average speed of all buses (local and regional) is 30.7 km/h (CROW-KpVV, 2024). This value is indicated with a red dotted line in the figure as a reference.

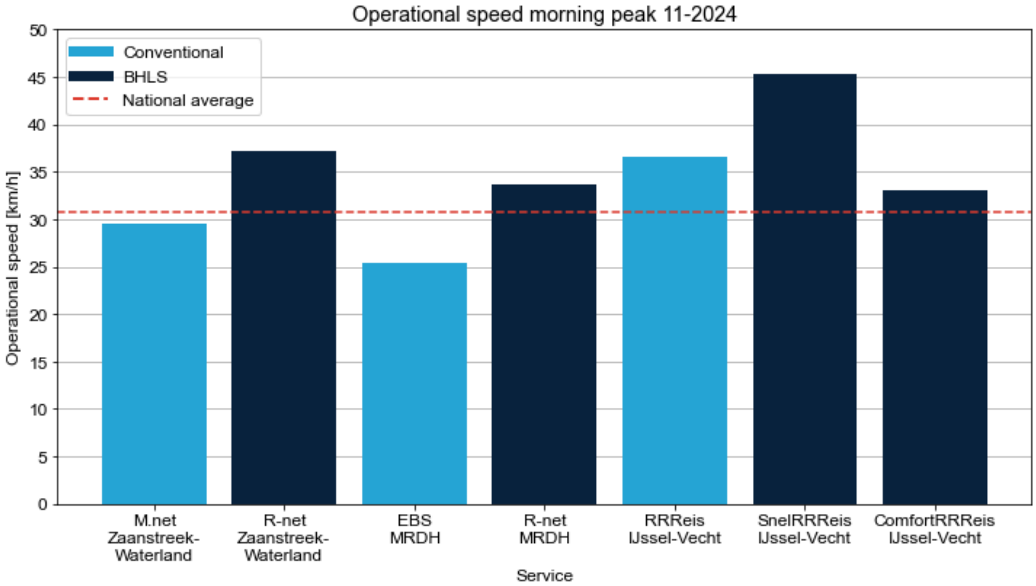

Figure 5.1 Operational speed per service

Except for *comfortRRReis*, all BHLS services have a significant higher operational speed compared to the conventional services in the same region (see Appendix B for statistical test results). For *comfortRRReis*, no statistical test is suitable because of the combination of unequal variances and the small sample size of *comfortRRReis*. The effect size of the comparison is -0.74. This means that the average operational speed of *comfortRRReis* is lower than that of *RRReis*. The effect size is not considered to be large. For the off-peak analysis, a statistical test is possible because the variances of the *comfortRRReis* and *RRReis* operational speed data sets are equal. Off-peak, there is no statistically proven difference between the operational speed of *comfortRRReis* and *RRReis*. The fact that there is no improvement in the operational speed of *comfortRRReis* is against expectations because the speed is one of the highlighted features in the brand guide (RRReis (1), n.d.). All other BHLS services are faster than the conventional services in the same region during the off-peak hours.
Finn, et al. (2011) observe average operational speeds between 12 and 37 km/h in their considered BHLS case studies. All average speeds of the services in this case study area are within this range, except for *snelRRReis*, which has an even higher average speed of about 45 km/h. Most services in the work of Finn, et al. have an average speed below 25 km/h which is the lowest observed average speed in this case study area. The operational speed of services in this case study area is thus quite high in an international context. This even goes for conventional services. The fact that Dutch bus travellers rate the speed of their bus trip with 8.1/10 points confirms that the speed of Dutch buses is very decent (CROW, 2024).
Although all services already have a speed which falls within the range of BHLS systems in other regions or countries, the speed is still a distinguishing aspect of most BHLS services in the case study area.

5.2 Reliability

As described in Section 3.2, the reliability is split into two parts: punctuality and cancellations. The performance of conventional and BHLS services on those two aspects are described in this section.

5.2.1 Punctuality

The punctuality for the different services according to the CROW-KpVV method as described in Chapter 3 can be found in Figure 5.2. The Dutch national average punctuality of all buses (local and regional) is 80% (CROW-KpVV, 2024). This value is indicated with a dotted line as a reference.

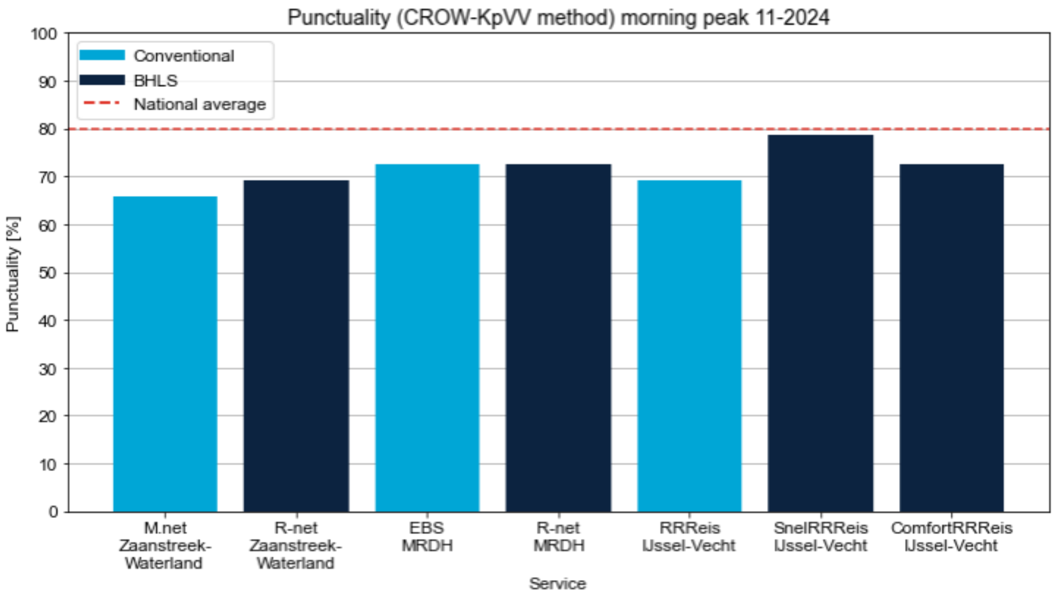

Figure 5.2 Punctuality per service

What stands out from Figure 5.2 is none of the services has an average punctuality which exceeds the national average of 80%. This is not entirely against expectations because busy roads and high occupancy levels during the peak can lead to large deviations and uncertain travel times. The lower punctuality during the peak hours could be compensated by a higher punctuality outside the peak hours to still meet the national average. The 12:00h – 14:00h punctuality analysis generally showed some improvements over the punctuality during the peak (details in Appendix B). However, the off-peak average punctuality of all services still does not exceed the national average.

R-net and *comfortRRReis* services do not have a statistically proven better punctuality compared to the conventional services in the same region (see Appendix B for statistical test results). This is observed during the morning peak as well as during the off-peak. *SnelRRReis* does have a better punctuality during the morning peak. However, off-peak *snelRRReis* also has no better punctuality than the conventional service. The results suggest that no different strategy is applied for BHLS services to make them more punctual than conventional services. The absence of an above-average punctuality for BHLS services is against expectations because this was found to be an important aspect in the literature review in Chapter 2 and it is one of the core features of *R-net* (R-net, 2023).

Because there are many possible definitions of punctuality, it is hard to put the findings in an international perspective properly. Finn, et al. (2011) report the average punctuality of four BHLS case studies that use the same punctuality thresholds. In those cases, a bus is considered to be on time if it departs no earlier than 1 minute before, and no later than 5 minutes after the scheduled departure time. The punctuality observed is between 93 and 97.6%. With a simple python script, the punctuality using these thresholds is computed for the case study area of this work. During the morning peak, the average departure punctuality was 94% on average over the entire case study area. This falls within the range of the case studies Finn, at al. (2011) discuss. Thus, although the punctuality of BHLS is not better than on conventional services and does not exceed the national average on the two considered time slots, the punctuality could on average still be considered as BHLS-like in an international perspective.

5.2.2 Cancellations

The percentage of cancelled service kilometres per service is presented in Figure 5.3. In Zaanstreek-Waterland, the average cancellation rate may not exceed 0.5% over a period of 3 months (Vervoerregio Amsterdam, 2021). In IJssel-Vecht, the cancellation rate may not exceed 0.2% per month (Provincie Flevoland, Provincie Gelderland, & Provincie Overijssel, 2021). In MRDH, there is no such requirement from the transit authority. Instead, the authority asks operators to make maximum efforts to avoid cancellations (MRDH, n.d.). The requirements from the authorities are included in Figure 5.3 as a reference.

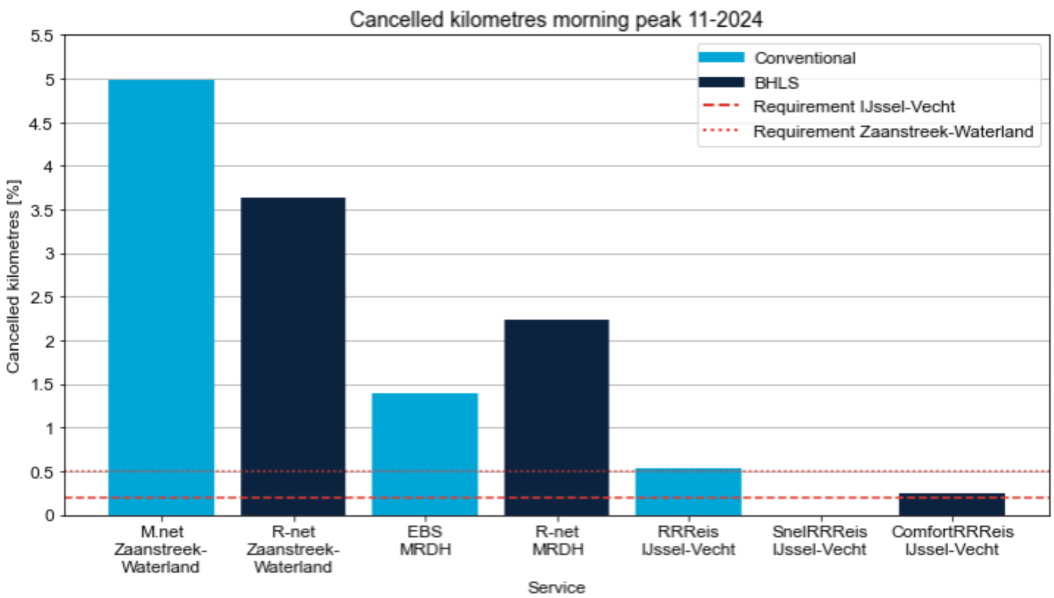

Figure 5.3 Cancelled kilometres per service

What stands out from Figure 5.3 is that the percentage of cancelled kilometres is high compared to the requirements. Especially in Zaanstreek-Waterland as there were issues with the operations of the new electric fleet. The cancellation rates between 12:00 – 14:00h are substantially lower in most regions (see Appendix B for the exact numbers). This can be explained by the fact that less drivers and vehicles are needed outside the peak hours. In case of shortage, the moments when most buses and drivers are needed are affected first. There are no significant differences in cancellation rates of BHLS services and conventional services in any of the regions. This holds for

the morning peak as well as the considered off-peak timeslot (see Appendix B for statistical test results).
It can be concluded that generally the reliability of BHLS services is not better compared to conventional services. Next to that, BHLS services do not exceed the national average punctuality and generally do not seem to meet the requirements for cancellations. Finn, et al. (2011) report the availability rate of 7 case studies. They observe an availability of at least 98% in those cases which means that less than 2% of the services is cancelled. On average, only conventional services in MRDH and the services in IJssel-Vecht align with these numbers although *R-net* in MRDH is quite close. So, according to the local requirements, the cancellation rate is too high. However, in an international perspective, only the services in Zaanstreek-Waterland are seriously underperforming.
In the case study area, reliability is not proven to be a distinguishing aspect of BHLS when comparing its performance to conventional services. However, the reliability of most services is at an BHLS-like level considering international case studies.

5.3 Frequency

The frequencies during the morning peak can be found in Figure 5.4.

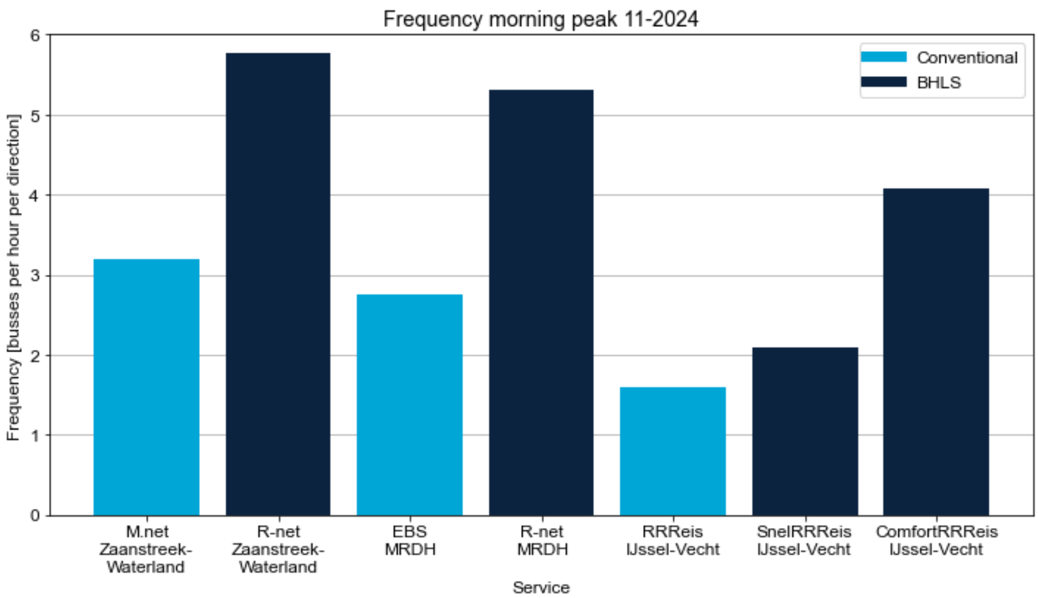

Figure 5.4 Morning peak frequency per service

All BHLS services have a higher frequency during the morning peak compared to the conventional services in the same region (see Appendix B for statistical test results). The difference between *snelRRReis* and *RRReis* is smaller than for the other BHLS brands but still statistically relevant. Based on these results, frequency can be seen as one of the distinguishing aspects of BHLS in practice. However, the frequency is not as high as found in literature. In most of their assessed case studies, Finn, et al. (2011) observe a frequency of *at least* 6 buses per hour. Dutch bus travellers rate the frequency with 7.0/10 points (CROW, 2024). This rating is low compared to the ratings on other aspects on bus transit. This means that generally speaking, there is room for improvement when it comes to the frequency.

5.4 Recognisability

BHLS services often have their own distinctive identity (see Chapter 2). This also goes for the BHLS services in the case study area. The BHLS brands have already been explained in the case study introduction in Chapter 4.
In theory, BHLS services are clearly recognisable from their branded vehicles. Vehicles carry a livery which is distinguishable from conventional services and have a BHLS brand icon (see Figure 5.5). However, in practice, not always the correct vehicles are deployed. In November 2024, this was especially the case for *snelRRReis* in IJssel-Vecht and *R-net* in Zaanstreek-Waterland. Those services were often carried out by vehicles with the conventional branding. *SnelRRReis* services were carried out by *snelRRReis* branded vehicles in only 0 – 20% of the trips. For most *R-net* services in Zaanstreek-Waterland, about 60% of the trips were carried out by vehicles with the correct branding (percentages based on trip recordings of the morning peak in November 2024). Deploying conventional vehicles on BHLS lines has a negative impact on the recognisability.

Figure 5.5 BHLS brand icons (R-net, 2023; RRReis (1), n.d.)

Apart from the visual differences on the vehicles, there are other ways in which BHLS services are recognisable. BHLS brand names are for example displayed in travel planning apps like the NS Reisplanner or 9292. In Figure 5.6, two examples of departure times from the 9292 app. The left example shows how *RRReis*, *snelRRReis*, and *comfortRRReis* are indicated. The right example shows how *R-net* buses are indicated.

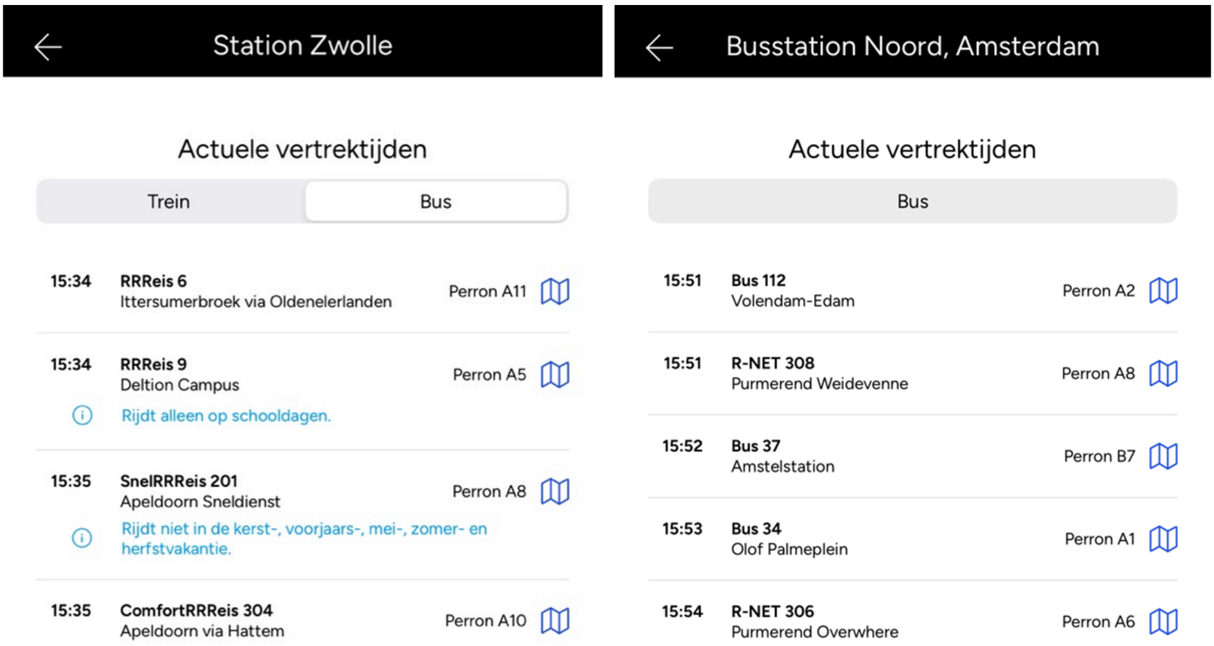

Figure 5.6 Brands indicated in the 9292 app

Next to that, BHLS services are recognisable from their (high) line number. In the case study area, BHLS brands have an own range of line numbers (see Table 5.2).

Table 5.2 Line numbers per brand

Service	*Line number range*
Conventional regional services	≤ 199
R-net Zaanstreek-Waterland	300 – 399
R-net MRDH	400 – 499
snelRRReis IJssel-Vecht	200 – 299
comfortRRReis IJssel-Vecht	300 – 399

BHLS services are visually different from conventional services. Although not always the vehicles with the right livery are deployed, BHLS services are always recognisable from their name in travel planning apps and high line numbers. The fact that BHLS services are distinguishable from conventional services does not necessarily mean that they are recognisable as being a high-quality service. The brand names *snelRRReis* and *comfortRRReis* have an indication in their names what the services offer compared to *RRReis* services: higher speed and a higher level of comfort respectively. In other words, by their brand names, the services are recognisable as services that are better than the conventional buses. Conversely, *R-net* does not have an indication of the meaning of the brand in its name. None of the objectives of *R-net* as described in Section 4.2 is reflected in the brand name. It is therefore not a given that this brand is recognised as high-quality. According to Devney (2011), the branding must easily be understood by the passengers for it to be successful. Finn, et al. (2011) agree upon this and state that a strong identification is needed to recognise the service as high quality of service. *R-net* could potentially be seen as another bus operator instead of a high-quality brand. What the public image of *R-net* is, is unfortunately unknown and might be valuable to be investigated in future work. Next to that, it is debatable whether the BHLS brandings are applied consistently. Although for example the speed and frequency of BHLS buses is on average higher, on individual lines, conventional services may outperform them on at least one of those aspects. BHLS services not consistently outperforming conventional services might obscure the high-quality image of a branding.

5.5 Availability

Literature shows that BHLS services have an improved availability due to wider operation hours. The availability is expressed in the off-peak frequency (12:00h – 14:00h) and the evening frequency (19:00h – 21:00h). The results per service can be found in Figure 5.7.

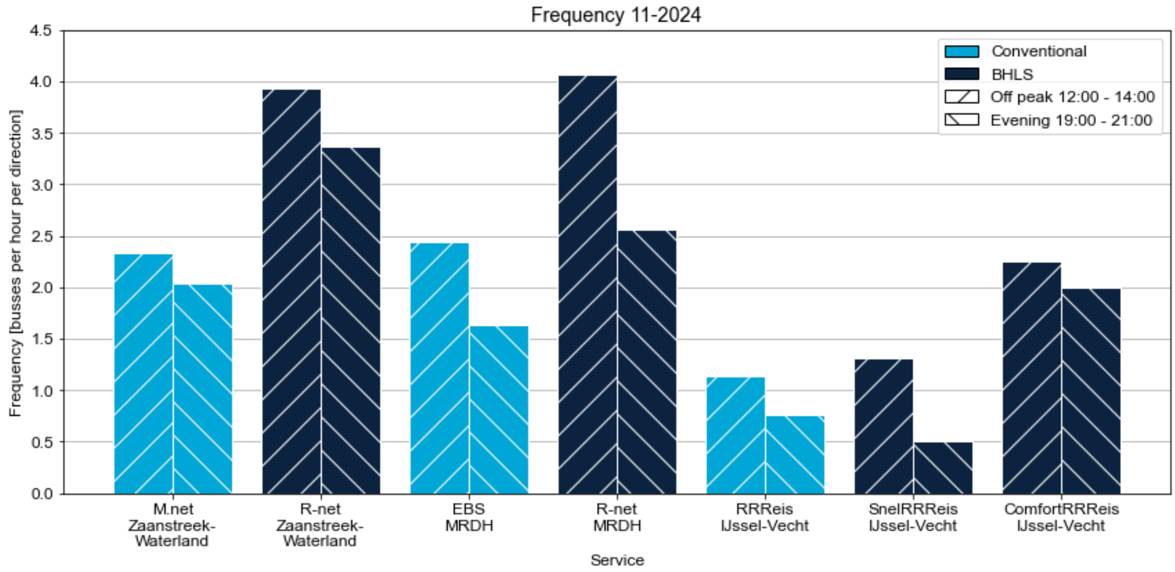

Figure 5.7 Frequency outside peak hours per service

The *R-net* and *comfortRRReis* services have statistically proven higher off-peak and evening frequencies compared to the conventional services in the same region (see Appendix B for statistical test results). *SnelRRReis* does not have statistically proven different off-peak and evening frequencies. In each area, there is a BHLS service that has a better availability compared to the conventional service in the same region. This is in line with the expectations based on the findings in the literature review. The improved availability because of wide operation hours can be seen as one of the distinguishing aspects of BHLS in practice. Because none of the works from the literature study give examples what a good availability due to wide exploitation hours is, it is not possible to compare the performance to other BHLS systems.

5.6 Comfort

The comfort of the services is based on the stop design and the seat availability. This section describes the performances of BHLS and conventional services on those aspects.

5.6.1 Stop design

Three aspects that make a stop more comfortable are considered: the presence of a shelter, bicycle parking facility and DRIS panel. The information about the stops is retrieved from the CHB. When matching the CHB data to the list of stops per line, it appeared that some quay codes do not match and that there is some missing data for specific quays in the CHB. The number of missing data points due to a mismatch or missing data in the CHB is very limited. The effect of the missing data is not expected to be significant.

The percentage of stops with a shelter along the line per service can be found in Figure 5.8.

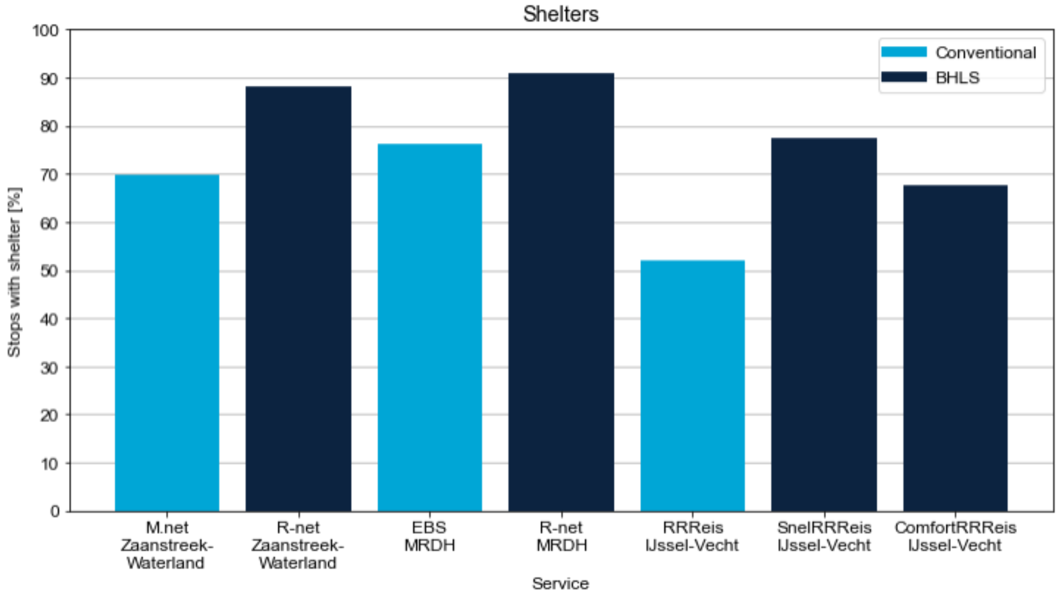

Figure 5.8 Stops with a shelter per service

R-net in Zaanstreek-Waterland and *snelRRReis* in IJssel-Vecht have statistically proven more shelters along the line. Although the other BHLS services visually also seem to have more shelters along the line, the difference is found to be not statistically relevant.
The share of stops with a bicycle parking facility along the line per service can be found in Figure 5.9.

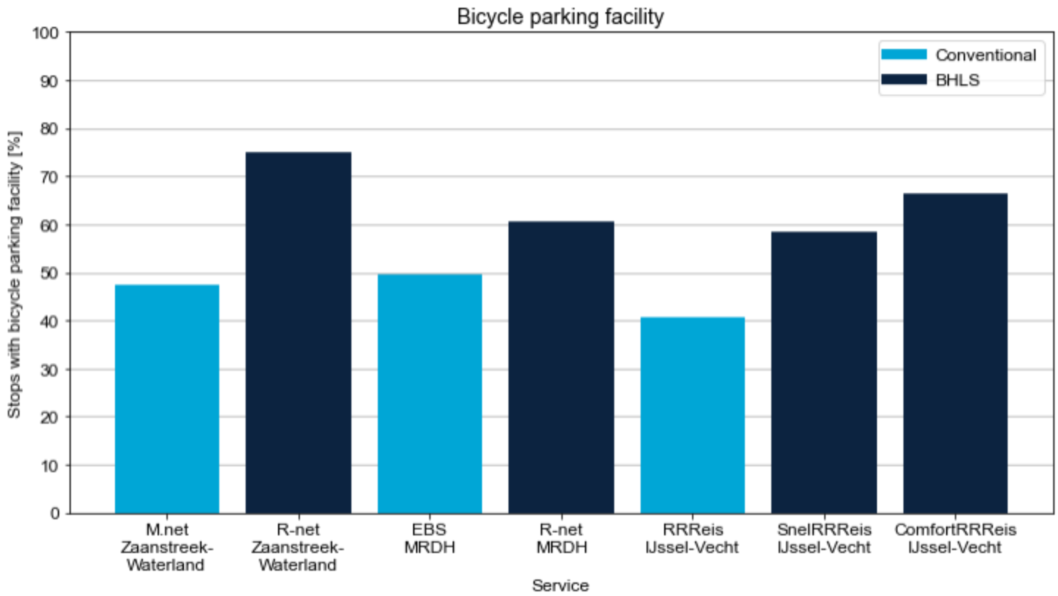

Figure 5.9 Stops with bicycle parking facility per service

Except for *R-net* services in MRDH, all BHLS services have significantly more bicycle parking facilities along their lines compared to conventional services.

The percentage of stops with a DRIS panel can be found in Figure 5.10.

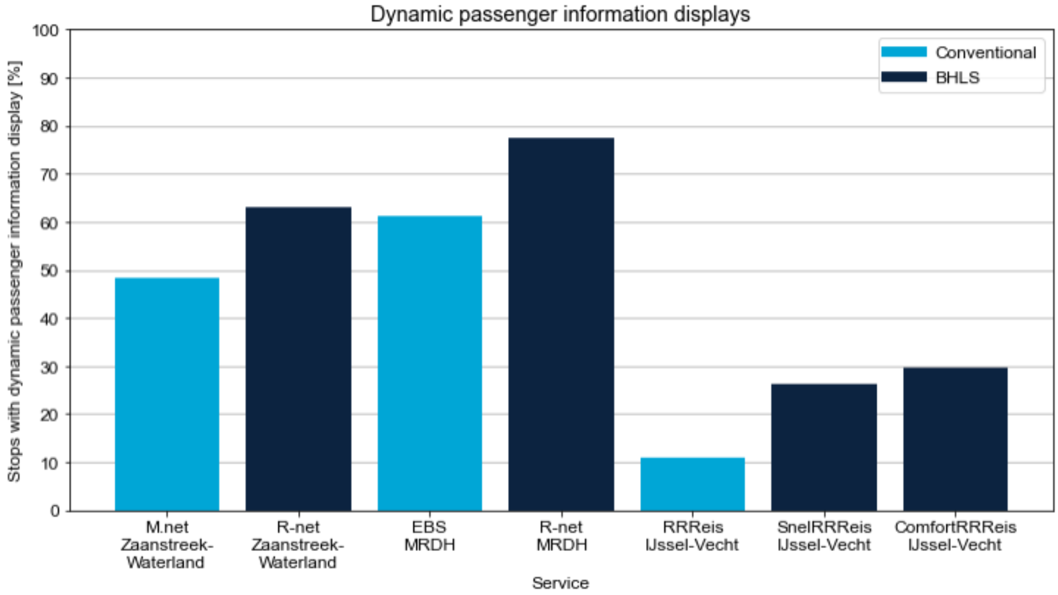

Figure 5.10 Stops with DRIS panel

R-net in Zaanstreek-Waterland and *comfortRRReis* services in IJssel-Vecht have statistically proven more DRIS panels along their routes compared to conventional services in the same region (see Appendix B for statistical test results). In MRDH, no statistical test is possible because the variances of the datasets are unequal, and the *R-net* dataset only contains 4 datapoints. The effect size for DRIS panels in MRDH is 0.60. This means that *R-net* services have slightly more DRIS panels along their routes. The effect size is not considered large.
What stands out from Figure 5.10 is that the number of DRIS panels in IJssel-Vecht is low compared to the other regions. In IJssel-Vecht, there is an alternative for DRIS panels. Each stop is provided with a QR-code which directs to a website with actual departure times (Figure 5.11). This sort of online version of a DRIS panel is easy and relatively inexpensive to implement and maintain. The use of this online DRIS panel is actively promoted in the buses (Figure 5.12).

Figure 5.11 Online version of DRIS panel

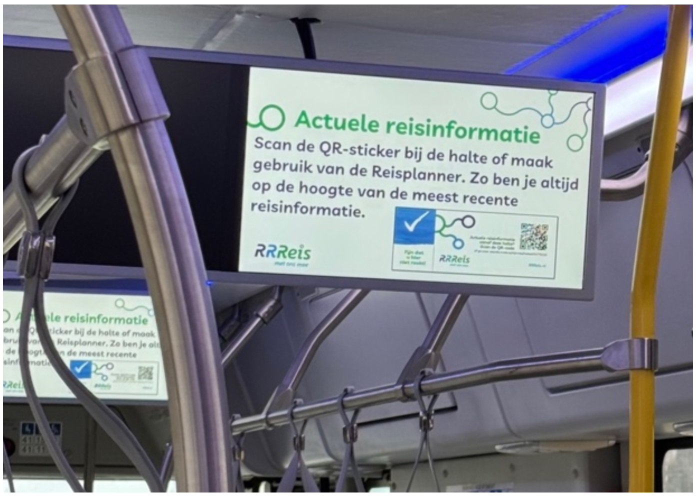

Figure 5.12 Promotion online DRIS panel in a bus

“Scan the QR sticker at the stop or use the travel planner. This way, you are always up to date with the latest travel information.”

From this sub-section, it can be concluded that the stops along BHLS lines are always more comfortable compared to the stops along conventional lines. On each of the three aspects, there is at least one BHLS brand that outperforms the conventional brand within the same region. However, there is also at least one brand that does not for each aspect. Whether a BHLS bus stop is more comfortable and which design features are implemented are location dependent. In the literature review, it was observed that the stop design is not always seen as an aspect of BHLS. The brand guides of the BHLS services in the case study area also not explicitly mention that the services should have more comfortable stops. Therefore, the results here are not completely against expectations.

5.6.2 Seat availability

Next to the stop design, the seat availability is part of the comfort of BHLS. The seat availability is determined at two levels. The first is that everyone is able to sit (occupancy ≤ 100% of the seat capacity) along at least 90 percent of the line. The second is that everyone can take a seat without someone next to them (occupancy ≤ 50% of the seat capacity) along at least 90 percent of the line. The results can be found in Figure 5.13.

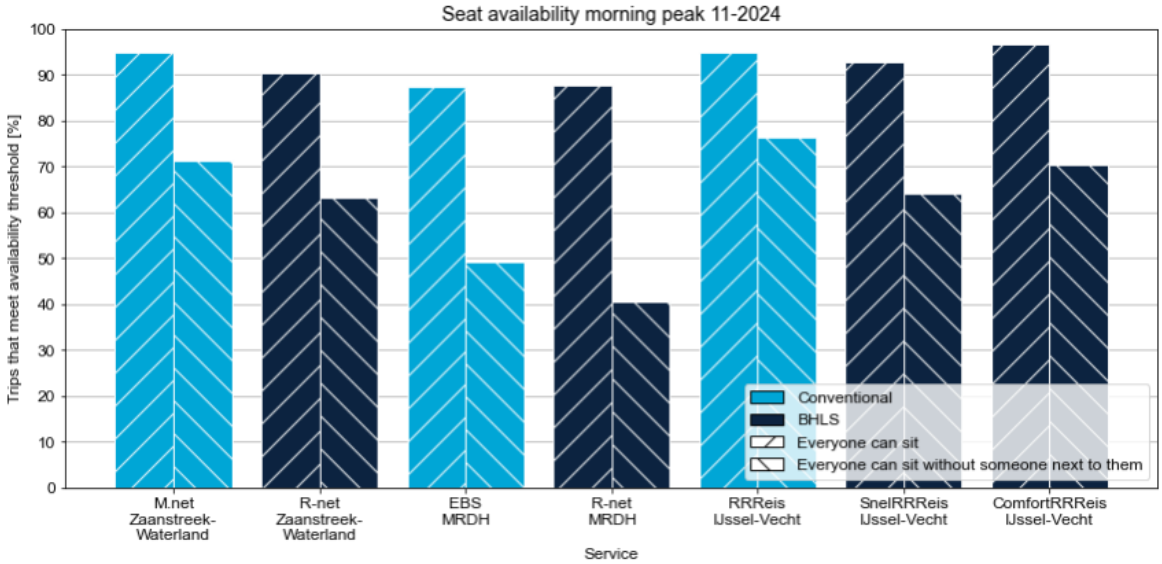

Figure 5.13 Seat availability per service

For both levels in all regions, there are no significant differences in seating chance between BHLS and conventional services. This holds for the peak hours as well as the off-peak hours. It must be noted that seating chances are quite high. Only on about 10% of the trips, people need to stand for a longer section during the peak hours. Off-peak, this percentage is even lower.

In the current method, a trip is considered crowded as it exceeds (half of) the seat capacity on more than 10% of the stops along the line. This is quite a strict requirement. A less strict requirement (e.g. a bus is crowded if the seat capacity is exceeded on 20% of the line) would result in an even higher seat availability.

The seat availability is higher than on other BHLS services like in Paris, Nantes, Prague, and Gothenburg (Finn, et al., 2011). Also, Dutch bus travellers seem to be very satisfied and rate the seating chance with 8.6/10 points (CROW, 2024). So, the fact that there is no difference between BHLS and conventional services does not mean that BHLS performs bad or that it does not comply with the seat availability aspect as found in literature. In fact, the performance is very good. In the case study area, a high seating chance is not necessarily a BHLS aspect but rather an aspect of all regional bus services.

5.7 Conclusion comparison

In Table 5.3, an overview of the findings from the comparison can be found. The table shows whether BHLS generally outperforms conventional services on the aspects of BHLS.

Table 5.3 Conclusions comparison

Aspect	*BHLS performs better*	*Remark*
Speed	yes	Not true for *comfortRRReis*
Reliability	no	Reliability is relatively good on all services in an international perspective
Frequency (7-9h)	yes	Most notable performance difference, but there is room for improvement
Recognisability	yes	BHLS services all have a dedicated branding, but it is potentially not always recognisable as being of high quality.
Availability	yes	Not true for *snelRRReis*
Stop design	yes/no	Performance strongly differs per region
Seat availability	no	Seating chance on all services is very good

It can be concluded BHLS does not always perform better on the aspects found in literature. BHLS services generally have a higher speed and a higher frequency (also outside the peak hours) in the case study area. The frequency shows the most notable performance increase over conventional services out of all aspects. However, the frequency is not as high as in other BHLS systems around the world. The speed and frequency are amongst the most common listed aspects of BHLS in literature according to the literature review in Chapter 2. The fact that BHLS services outperform conventional services on those aspects in the case study area is in line with the expectations based on literature.
Next, all BHLS services are branded although it is questionable if all brands are actually recognisable as being of high-quality. This especially goes for *R-net* which has no high-quality feature in its name. The fact that the services in the case study area have a different livery aligns with literature. However, the application of the recognisability aspect is not as prescribed by literature in the sense that is possibly not easily understandable. This can affect the relation between the recognisability and ridership which is investigated in Chapter 6. A high speed, high frequency and branding thus are the three main distinguishing aspects of BHLS in the case study area.
Findings in the comparison do not point to one single direction when it comes to the stop design. The aspects on which BHLS outperforms conventional services vary per region. As can be seen in the literature review, the stop design is not always acknowledged as part of BHLS. In that sense, the findings in practice are not necessarily contradicting to literature. In this work, features are considered equally important at all stops. However, the level of comfort of one stop is more important than of the other in reality. The importance of a stop could be determined by the number of passengers that uses a stop. If a methodology would be used where the stop design features are determined per passenger (e.g. X percent of the passengers on line Y could wait at a shelter at their departure stop), other results are likely to be found. Assuming infrastructure managers start with upgrading the most-used stops, the percentages for the stop design features would likely be higher. The shortage of this approach is that the percentages are more complex to compute and vary over the day because of varying travel patterns.
The comparison shows that there are hardly any improvements for the reliability of BHLS services over the conventional services. This is against the findings in the

literature review where the reliability turned out to be amongst the most mentioned aspects. The reliability is also a key feature of *R-net* according to its brand guide. BHLS is thus not more reliable than conventional services. However, as discussed in Section 0, the punctuality of all services could be considered as BHLS worthy in an international perspective. To a smaller extent, this also applies to the cancellation rate where only services in Zaanstreek-Waterland are underperforming compared to other BHLS systems. It can be concluded that the reliability in the case study area is not necessarily a BHLS aspect but rather a bus transit aspect. Highlighting the reliability as a key aspect of *R-net* is therefore arguably not very appropriate.

Lastly, the seat availability of BHLS is not different compared to conventional services. However, the chance of being able to sit is quite high, no matter whether the service is BHLS or not. The seat availability is higher than on other BHLS services and Dutch passengers are very satisfied with the seat availability (CROW, 2024). It could therefore be considered as an aspect of all regional buses in the case study area instead of a BHLS aspect only.

All things considered, BHLS in the case study area is not as different compared to conventional services as would be expected based on literature. This is not because BHLS services have a poor performance but mainly because the performance of conventional services is already quite good.

6 Relation between BHLS and Ridership

In this chapter, the relation between the aspects of BHLS and ridership is investigated using a multiple linear regression model. The input variables for the model are the performances on BHLS aspects of the relevant bus lines in the network and the number of boarding passengers on those lines (see Section 3.3). The tables with results displayed in this chapter are for the morning-peak model. The tables with results for the off-peak model can be found in Appendix D.

6.1 Model development

In this section, the development of the regression model is prepared. This is done by setting up constraints of which variables may not occur in the model at the same time and determining which regression coefficients should be estimated on a regional scale.

6.1.1 Testing for high correlations

The first step in developing the model is determining the Pearson correlation matrix. The correlation matrix can be used to determine if there are predictors that should not be in the model at the same time because of a high correlation. The correlation matrix can be found in Table 6.1. Correlations between different predictors that are above |0.7| are indicated in red.

Table 6.1 Correlation matrix BHLS aspects

	Speed	*Punctuality*	*Cancelled kilometres*	*Frequency 7h - 9h*	*Frequency 12h - 14h*	*Frequency 19h - 21h*	*Bicycle Parking*	*Shelter*	*DRIS*	*BHLS service*	*BHLS vehicles*	*Stops*
Speed	1	.23	-.170	-.038	-.300	-.248	.294	-.042	-.393	.429	.060	-.200
Punctuality	.230	1	-.059	.054	-.034	-.063	.235	.125	-.012	.212	.015	-.247
Cancelled kilometres	-.170	-.059	1	.442	.386	.464	.220	.265	.370	.012	.189	-.225
Frequency 7h - 9h	-.038	.054	.442	1	.840	.810	.600	.552	.659	.579	.750	-.406
Frequency 12h - 14h	-.300	-.034	.386	.840	1	.839	.450	.528	.693	.464	.686	-.324
Frequency 19h - 21h	-.248	-.063	.464	.810	.839	1	.423	.410	.581	.363	.593	-.289
Bicycle Parking	.294	.235	.220	.600	.450	.423	1	.597	.335	.510	.444	-.392
Shelter	-.042	.125	.265	.552	.528	.410	.597	1	.585	.480	.437	-.500
DRIS	-.393	-.012	.370	.659	.693	.581	.335	.585	1	.281	.436	-.361
BHLS service	.429	.212	.012	.579	.464	.363	.510	.480	.281	1	.776	-.386
BHLS vehicles	.060	.015	.189	.750	.686	.593	.444	.437	.436	.776	1	-.258
Stops	-.200	-.247	-.225	-.406	-.324	-.289	-.392	-.500	-.361	-.386	-.258	1

In the correlation matrix, a few high correlations can be observed. The pairs that are highly correlated are:

- Frequency 7:00h – 9:00h and Frequency 12:00h – 14:00h
- Frequency 7:00h – 9:00h and Frequency 19:00h – 21:00h
- Frequency 12:00h – 14:00h and Frequency 19:00h – 21:00h
- Frequency 7:00h – 9:00h and BHLS vehicles
- BHLS service and BHLS vehicles

Those pairs should thus not occur in the regression model such that the assumption of no high correlations is not violated. The pairs that are highly correlated are not completely unforeseen. It is to be expected that lines with a high frequency during the morning peak, also have a high off-peak and evening frequency. The high correlation between the frequencies over the day mean that the relation between the availability and ridership cannot be investigated. Because of the high correlations, the model must be restricted in such a way that it is not possible research the relation between a high frequency throughout the entire day and ridership. Another definition of the availability due to wide exploitation hours could have avoided the high correlations.

The high correlation between the morning peak frequency and the deployment of BHLS vehicles can be explained based on the combination of two findings in Chapter 5, related to the frequency and the BHLS vehicle deployment. In the comparison, it was found that BHLS services have a higher frequency than conventional services. This means that there is a correlation between the frequency and BHLS services and thus between the frequency and the BHLS vehicle deployment. For *snelRRReis*, the frequency was relatively low compared to other BHLS services and even compared to conventional services in the Randstad area. This has a damping effect on the correlation between the frequency and BHLS services. However, only 0 – 20% of the *snelRRReis* trips are carried out by BHLS vehicles. Therefore, the correlation between frequency and BHLS vehicles becomes sort of a correlation between frequency and the most frequent BHLS services. This causes a high correlation between frequency and BHLS vehicles.

A high correlation between BHLS service and BHLS vehicles should be a given. Ideally, the correlation would be 1. This would mean that all BHLS services are being carried out by the correct vehicles.

Off-peak, same pairs of highly correlating variables are observed (correlation matrix in Appendix D). In addition to that, correlations above |0.7| are found between Frequency 12:00h – 14:00h and DRIS and Frequency 12:00h – 14:00h and BHLS vehicle deployment. These pairs already had correlations close to |0.7| in the morning peak correlation matrix and just exceeded the threshold in the off-peak.

6.1.2 Exploring the need for regional regression coefficients

Before the model is built, an ANOVA is performed for each aspect to verify whether one regression coefficient per aspect is enough. The ANOVA test results can be found in Table 6.2. The variable BHLS service is not included in the ANOVA because this is a binary indicator variable. The variable BHLS vehicles deployed on BHLS lines is also not included in the ANOVA. This choice was made because of the limited number of BHLS lines. Estimating regression coefficients per region for a predictor which is only related to the BHLS lines would result in a very low number of data points per regression coefficient.

Table 6.2 ANOVA test results

Aspect	F test result	p-value
Operational speed	17.32	0.000
Punctuality	2.32	0.106
Cancelled kilometres	38.13	0.000
Frequency 7:00h – 9:00h	24.60	0.000
Frequency 12:00h – 14:00h	36.97	0.000
Frequency 19:00h – 21:00h	33.33	0.000
Bicycle parking	3.23	0.045
Shelter	11.66	0.000
DRIS	57.21	0.000
Number of stops	2.63	0.079

As can be seen in Table 6.2, only punctuality and the number of stops have a *p*-value above 0.05. This means that the effect on ridership of those two variables can be estimated with only one regression coefficient. For all other variables, a t-test is performed to test whether the effect on ridership in Zaanstreek-Waterland and MRDH can be estimated with one regression coefficient ($\beta_{i,Randstad}$). The test results are listed in Table 6.3

Table 6.3 t-test results BHLS aspects (Zaanstreek-Waterland - MRDH)

Aspect	t-test result (absolute value)	p-value
Operational speed	2.88	0.007
Cancelled kilometres	4.29	0.000
Frequency 7:00h – 9:00h	2.01	0.052
Frequency 12:00h – 14:00h	0.82	0.415
Frequency 19:00h – 21:00h	2.50	0.017
Bicycle parking	1.17	0.250
Shelter	0.24	0.812
DRIS	1.52	0.137

Based on the results in Table 6.3, a $\beta_{i,Randstad}$ can be used for the following aspects:

- Frequency 7:00h – 9:00h
- Frequency 12:00h – 14:00h
- Bicycle parking
- Shelter
- DRIS

Those aspects have a *p*-value above 0.05 which means that the difference of the mean performance between Zaanstreek-Waterland and MRDH is not statistically relevant at the 95%-confidence interval. An overview of the regression coefficients that are estimated can be found in Table 6.4.

Table 6.4 Regression coefficients to be estimated

Aspect	*Base model*	*Model with regional coefficients*
Speed	β_{speed}	$\beta_{speed,ZaWa}$; $\beta_{speed,MRDH}$; $\beta_{speed,IJV}$
Punctuality	$\beta_{punctuality}$	$\beta_{punctuality}$
Cancelled kilometres	$\beta_{cancelled}$	$\beta_{cancelled,ZaWa}$; $\beta_{cancelled,MRDH}$; $\beta_{cancelled,IJV}$
Frequency 7:00h – 9:00h	$\beta_{freq\ 7-9}$	$\beta_{freq\ 7-9,Randstad}$; $\beta_{freq\ 7-9,IJV}$
Frequency 12:00h – 14:00h	$\beta_{freq\ 12-14}$	$\beta_{freq\ 12-14,Randstad}$; $\beta_{freq\ 12-14,IJV}$
Frequency 19:00h – 21:00h	$\beta_{freq\ 19-21}$	$\beta_{freq\ 19-21,ZaWa}$; $\beta_{freq\ 19-21,MRDH}$; $\beta_{freq\ 19-21,IJV}$
Bicycle Parking	$\beta_{bicycle}$	$\beta_{bicycle,Randstad}$; $\beta_{bicycle,IJV}$
Shelter	$\beta_{shelter}$	$\beta_{shelter,Randstad}$; $\beta_{shelter,IJV}$
DRIS	β_{DRIS}	$\beta_{DRIS,Randstad}$; $\beta_{DRIS,IJV}$
BHLS service	$\beta_{BHLS\ service}$	$\beta_{BHLS\ service}$
BHLS vehicles deployed on BHLS lines	$\beta_{BHLS\ vehicle}$	$\beta_{BHLS\ vehicle}$
Number of stops	β_{stops}	β_{stops}

For the majority of the aspects, a regional regression coefficient will be estimated besides the base model. The model outputs between the base model and the model with regional regression coefficients can therefore quite different. Since there are many more predictor variables, the fir of the model with regional coefficients is likely to have a higher R^2. However, a higher number of predictors also comes with an increased risk of overfitting. Also, since there are less data points per predictor for regional regression coefficients, the fit can be less stable.
Off-peak, the list of regional regression coefficients looks slightly different. Off-peak, there is no statistical relevant regional difference in cancelled kilometres and bicycle parking facilities, so no regional coefficients are estimated for those variables. On the other hand, there is a statistically relevant difference between the number of stops per line in the Randstad area and IJssel-Vecht, so a regional regression coefficient is estimated for that. The share of stops with a bicycle parking and the number of stops per line of course do not change over the day if buses keep running the same route throughout the day, which is true for almost all lines. However, the differences between regions for those variables can be significant in one moment of the day and insignificant on another moment of the day. This can be explained by the different composition of lines that is used for the analysis. Some line that are included in the morning peak model do not run off-peak and are thus not included in the off-peak analysis. An overview of the ANOVA and t-test results and a list of the regression coefficients to be estimated for the off-peak can be found in Appendix D.

6.2 Model output

This section discusses the output of the regression analysis. First, the output of the base model without regional regression coefficients is reported. Then, the model with regional regression coefficients is discussed.

6.2.1 Base model without regional regression coefficients

In the first model run, the constraint that certain pairs of variables may not occur in the model at the same time because of their high correlation is neglected. This approach was chosen because it takes less computational effort to adjust a model that violates one or two constraints than modelling and running all possible versions where a violation of the constraints is prevented a priori. This strategy does not affect the final results. The initial output of the model violates the constraint that Frequency 7:00h – 9:00h and Frequency 12:00h – 14:00h may not occur in the model at the same time. This means an adjustment of the model is needed. Therefore, the model is estimated

again twice. First without Frequency 7:00h – 9:00h, then without Frequency 12:00h – 14:00h. The model without Frequency 12:00h – 14:00h has the highest R^2 (.722) of the two and thus will be selected as the final version of the base model. The standardised regression coefficients can be found in Table 6.5. The IBM SPSS Statistics output tables of this model can be found in Appendix C.
For the off-peak, no highly correlated variables occurred in the initial version of the base model. Therefore, the initial output is also the final output. The off-peak model has an R^2 of .739. The standardised significant regression coefficients can also be found in Table 6.5. Tables with the detailed output from IBM SPSS Statistics can be found in Appendix D.

Table 6.5 Standardised regression coefficients base models

Morning peak regression coefficients		*Off-peak regression coefficients*	
$\beta_{freqency\ 7-9}$	.722	$\beta_{freqency\ 12-14}$	.760
β_{speed}	-.189	$\beta_{shelter}$	.330
$\beta_{shelter}$	.371	β_{stops}	.435
β_{stops}	.304		
$\beta_{cancelled\ kms}$	-.193		

Both models have an R^2 above 0.7 indicating the fit is at least satisfactory. The coefficients from the base models show that the frequency has the strongest relation with ridership. Also the share of stops with a shelter and the number of stops occur in both the models. The operational speed and the cancelled kilometres only occur in the morning peak model. In this model, those aspects have the lowest standardised regression coefficient which means that the relation with ridership less strong compared to the other aspects.

6.2.2 Model with regional regression coefficients

Next to the base model, a model with region dependent regression coefficients is estimated. Again, in the first estimation of this model, the constraint that certain pairs may not occur in the model at the same time because of their high correlation is neglected. The initial output for the regression model with region dependent regression coefficients violates the constraint that frequencies for different moments in time may not occur in the model at the same time. Theoretically, a regression coefficients for the frequency for different moments in time could be estimated if they relate to different regions (e.g. $\beta_{freqency\ 7-9,Randstad}$ and $\beta_{freqency\ 12-14,IJV}$). However, this would make less physical sense compared to using the same moment in time when estimating the effect of frequency (e.g. $\beta_{frequency\ 7-9,Randstad}$ and $\beta_{freqency\ 7-9,IJV}$ or $\beta_{freqency\ 12-14,Randstad}$ and $\beta_{freqency\ 12-14,IJV}$). Therefore, the model is estimated three more times. First only with the 12:00h – 14:00h frequency, then only with the 7:00h – 9:00h frequency, and finally only with the 19:00h -21:00h frequency. This approach does not allow for frequency regression coefficients for different moments in time for different regions.
The model with only the option for Frequency 7:00h – 9:00h has an R^2 of .746, which is the highest of the three re-estimated models. The standardised significant regression coefficients in this model can be found in Table 6.6. The IBM SPSS Statistics output tables of this model can be found in Appendix C.
The final version of the off-peak model with regional coefficients has an R^2 of .840. This value is higher compared to the other R^2 values seen so far. This is probably

caused by the relatively high number of significant regression coefficients included in the model. The resulting coefficients can be found in Table 6.6. The detailed output from IBM SPSS Statistics can be found in Appendix D.
The models with regional regression coefficients both have a higher R^2 than the base models. The R^2 values are above 0.7 which means that the fits are at least satisfactory. Therefore, the models with regional coefficients are be considered as the final versions.

Table 6.6 Standardised regression coefficients regional models

Morning peak regression coefficients		*Off-peak regression coefficients*	
$\beta_{freqency\ 7-9,Randstad}$	.994	$\beta_{frequency\ 12-14,Randstad}$	1.216
$\beta_{freqency\ 7-9,IJV}$	.421	$\beta_{frequency\ 12-14,IJV}$	.728
$\beta_{speed,ZaWa}$	-.338	$\beta_{speed,ZaWa}$	-.241
$\beta_{shelter,Randstad}$	.804	$\beta_{speed,IJV}$	.676
$\beta_{shelter,IJV}$	.432	$\beta_{shelter,Randstad}$	.541
β_{stops}	.335	$\beta_{cancelled\ kilometres}$	-.163
		$\beta_{stops,Randstad}$	.756
		$\beta_{stops,IJV}$	.259

Like in the base model, the strongest relations with ridership are found for the frequency. Both models show a stronger relation in the Randstad area than in IJssel-Vecht. This could possibly be explained by the fact that the frequency in the Randstad area covers a wider range (1.50 – 7.00 compared to 1.00 – 4.25 buses per direction per hour). The operational speed shows a negative relation in Zaanstreek-Waterland in both models. This means that faster lines have lower ridership. The off-peak model shows the opposite for IJssel-Vecht where faster lines have higher ridership. In MRDH, no relation between the speed and ridership is observed. The large regional differences for the relation with ridership might explain why the relation in the morning peak base model is relatively weak and non-existing in the off-peak model. The share of stops with a shelter appears in both models, albeit only for the Randstad area in the off-peak model. This finding is in line with the base models. Off-peak, there is a slight negative relation found for the cancelled kilometres. This relation was also found in the morning peak base model. The fact that the relation is relatively weak could explain why the coefficient is only significant in certain compositions of regression coefficients. The stops show a significant relation with ridership in both models. This effect was also observed in the base models. It is not an aspect of BHLS but a variable which is introduced to compensate for the line length. The fact that this predictor is positive and significant confirms that the number of stops affects ridership.

6.3 Model validation

To test whether the model results are stable, the models are validated. The complete validation process of the morning peak model is discussed in this section. For the off-peak model, only the key take-aways of the validation are reported. The detailed validation results for the off-peak model can be found in Appendix D.
For the validation, the model is re-estimated five times based on random seeds of 80% of the data set. The original values of the regression coefficients and the re-estimated values for the different seeds can be found in Table 6.7. In the last column, the standard deviation of the estimated regression coefficients (including the original coefficient) is reported. A low standard deviation indicates few variations across the different seeds.

Table 6.7 Regression coefficients for different seeds (morning peak)

Regression coefficient	*Original*	*Seed 1*	*Seed 2*	*Seed 3*	*Seed 4*	*Seed 5*	*SD*
$\beta_{freqency\ 7-9,Randstad}$	.994	1.071	1.161	.878	.932	1.142	.104
$\beta_{speed,ZaWa}$	-.338	-.400	-.298	-.293	-.348	-.356	.036
$\beta_{freqency\ 7-9,IJV}$	.421	.420	.404	.379	.397	.486	.034
β_{stops}	.335	.295	.366	.322	.360	.300	.027
$\beta_{shelter,Randstad}$	.804	.817	.652	.866	.825	.732	.071
$\beta_{shelter,IJV}$	.432	.387	.500	.424	.440	.401	.036

The estimations of the regression coefficients do not show very large deviations across different seeds. The standard deviations are about 10% of the values of the regression coefficients. For the purpose of this model, this is considered to be good enough. Next to that, all coefficients remain statistically relevant at the 95% confidence interval.
Off-peak, standard deviations of the same order of magnitude are found. For this model, no large deviations are observed too. Most estimations of the regression coefficients remain significant within the 95% confidence interval. In two seeds, one insignificant regression coefficient occurred. The detailed results of the validation can be found in Appendix D.
The re-estimated coefficients are used to estimate ridership of the part of the data set which is not used for the re-estimation of the coefficients. For each seed, the RMSE is computed. The results for the morning peak model can be found in Table 6.8.

Table 6.8 RMSE for different seeds

	Seed 1	*Seed 2*	*Seed 3*	*Seed 4*	*Seed 5*
RMSE	4148.68	3740.50	2031.33	2553.78	4461.88

There is quite some variation in the RMSE across different seeds. For example, the RMSE of seed 5 is more than twice as high as the RMSE of seed 3. This indicates that the model is not a very stable predictor for ridership. Since predicting is not an objective of the model and the variation in the standardised regression coefficients is small, the model is still considered to be at least sufficiently good.
Off peak, the RMSE does vary way less across the different seeds compared to the morning peak model. This means that the off-peak model is a more stable predictor. Also, the RMSE of off-peak model are much lower. However, off-peak ridership is also substantially lower such that the RMSE is still relatively high. Also the fit of the off-peak model is considered to be at least sufficiently good.

6.4 Interpretation of model results

The interpretation of the results is based on the final versions of both the morning peak and the off-peak model. Those are the models with the regional aspects as these have a higher R^2 than the base models. First, the aspects with a significant relation with ridership and thus occur in the model are discussed. Then, the aspects that do not have a significant relation and are therefore excluded from the model are discussed.

6.4.1 Factors included in the model

In both the morning peak and the off-peak model, there is a convincing positive relation between the frequency at the moment of travelling and ridership. As discussed before, the relation is stronger in the Randstad area than in IJssel-Vecht which could be explained by the wider range of frequencies in the Randstad area. The strong positive relation aligns with the existing knowledge from survey-based studies. Borsje, et al. (2023) and Chen, et al. (2024) both find that the frequency is the most effective way to increase ridership.

The operational speed is a significant predictor in only some of the regions. In MRDH, no significant effects of the speed are observed. In IJssel-Vecht, a positive relation is observed, but only off-peak. In Zaanstreek-Waterland, a negative relation is observed which means that faster lines have lower ridership. This is against expectations because a high speed is an important aspect of BHLS, and according to literature, ridership is generally higher on BHLS lines.

A possible explanation for the negative relation could have to do with the local population density. In densely populated areas, lines could have lower speeds because there are more stops and the streets are more crowded. On the other hand, there is a larger ridership potential in more densely populated areas which has a positive effect on ridership on those slower lines. This theory is supported by the fastest and the slowest *R-net* lines in the concession area. The fastest line (315) has an operational speed of about 45 km/h and goes from Amsterdam Noord to Monnickendam which is a small city with roughly 10000 inhabitants (CBS, 2024). The slowest *R-net* service (394) has an operational speed of just under 24 km/h and goes from Amsterdam Noorderpark to Zaandam Station. Zaandam is with about 80000 inhabitants substantially larger than Monnickendam. The larger ridership potential in Zaandam might be part of the explanation why ridership on the bus from/to Zaandam is 2.75 times higher compared to the bus from/to Monnickendam. If the population density would have been included in the model, the results could have looked different with potentially no negative relations between the operational speed and ridership.

Because the relation between the operational speed and ridership can be – depending on the concession area – either positive, negative or non-existing, no general conclusions can be drawn about the effect of the operational speed on ridership.

The next aspect occurring in the model is the share of stops with a shelter. In the Randstad area, a significant positive relation is observed. In IJssel-Vecht, the relation is only significant in the morning peak model. What stands out is that this relation is quite strong, especially during the morning peak in the Randstad area, whilst other stop design aspects are not significant. Based on earlier research, also a positive relation with DRIS panels was expected because it reduces the perceived waiting time at the stop (Dziekan & Vermeulen, 2006). As already discussed in Chapter 5, online alternatives for a DRIS panel exist. Although it might be less convenient, passengers can still access the latest travel information through their mobile phone at stops without a DRIS panel. This might be the reason why the shelters are relatively more important than DRIS panels. The absence of a relation with bicycle parking facilities can potentially be explained because this is only relevant for those who use the bike as an access or egress mode. Shelat, et al. (2018) show that less than 30% of the passengers use the bicycle as access mode for the bus if the stop is within 1 kilometre (which is a little over the average stopping distance in the case study area) from their homes. The bicycle is used even less as egress mode. Whether there is a bicycle parking is thus irrelevant for the majority of the passengers.

For the cancelled kilometres, a significant negative relation is found off-peak. This means that a higher cancellation rate is associated with lower ridership. The standardised regression coefficient has a small value which indicates that the relation with ridership is relatively weak compared to the other relations with ridership.

Finally, the number of stops is a significant predictor variable in both models. It is not an aspect of BHLS but a variable which is introduced to compensate for the line length.

The fact that this predictor is positive and significant confirms that the number of stops affects ridership. If the number of stops were not included in the models, the results would have looked different with probably a lower R^2 value and a potential bias in the results.
An important remark is that a significant relation does not prove causality. Based on a positive relation, it is not possible to indicate whether for example ridership increases because there are more shelters along the line, or whether more shelters are placed because ridership is high. A significant relation does indicate that there is an interaction between the aspects and ridership which is very valuable information.

6.4.2 Factors not included in the model

The punctuality and recognisability do not show a significant relation with ridership in both models. This sub-section discusses possible explanations for the absence of significant relations. Also the share of stops with a DRIS panel and bicycle parking do not show a significant relation. Potential explanations for this are already discussed in Sub-section 6.4.1.
Punctuality does not show any relation with ridership which is against expectations since it is considered as a BHLS aspect in all the reviewed works in Chapter 2. Next to that, van Oort (2011) showed that improving punctuality can lead to a ridership increase of 5 to 15%. A hypothesis for why there is no relation with ridership in this case is that people do not decide to take the bus or not based on line-specific punctuality but on a more general image of the reliability of public transport. It is conceivable that if the majority of the lines in a network has a very poor punctuality, also the lines that have a good punctuality still have the image of an unreliable service. This hypothesis should be tested in future work. Another reason could be that delays only have a significant impact on ridership when they are large. In the CROW method, a bus is already considered delayed once it arrives more than 30 seconds after the scheduled arrival time. In this method, a delay of 40 seconds has the same effect on the punctuality as a delay of 7 minutes. Especially when passengers do not need to transfer after their bus trip, a delay of 40 seconds is likely to be neglectable. However, a delay of 7 minutes is presumable a noticeable delay for almost all passengers. Taking a closer look at the data set revealed that there is quite some variation in the punctuality beyond the thresholds from the CROW method. A definition of punctuality which includes the magnitude of the delay could result in a different – potentially significant – relation with ridership. Van Oort (2014) proposes such a method. In his method, also the number of passengers experiencing the delay (or early departure) is taken into account which makes the punctuality at heavily used stops more important than the punctuality at less used stops. The resulting indicator from this method is the average additional waiting time per passenger. This method is arguably more representative for the user experience compared to the CROW method used here. The advantage of the method used in this work is the substantially less computational effort it takes since only the punctuality is only computed at the beginning and the end point of the line.
Because earlier research showed that ridership could increase due to improved punctuality and results could be different if another method for punctuality would be applied, it would be improper to state that punctually has no effect on ridership at all. However, in this specific case study, it can be concluded that the relation with ridership for this definition of punctuality is not significant.
Ridership on BHLS lines is 88% higher than on conventional services in the morning peak and 71% higher off-peak. This finding is in line with the findings of Heddebaut, et al. (2010) and Finn, et al. (2011). However, this ridership increase is not explained by

classifying services as BHLS and giving them a different name. In the case study area, branding has not proven to influence ridership. There is also no relation between the deployment of BHLS vehicles and ridership observed. This hypothetically could have something to do with the questionable recognisability of the BHLS brandings as being a high-quality service as described in Chapter 5. Like discussed before, the branding of the BHLS services should be easily recognisable to be successful (Devney, 2011). Next to that, the recognisability might be obscured by incorrect vehicle deployment or the application of BHLS brandings on lines which do not perform well on most BHLS aspects. A different strategy of the deployment of the BHLS vehicles might lead to other results. There could potentially be a positive relation with ridership if the vehicles were solely deployed on only the lines that comply with all aspects of BHLS from literature.

6.5 Conclusion regression analysis

The analysis showed that a multiple linear regression model with regional aspects results in the best fit. Models for the morning peak and off-peak show similar results. The operational speed, which is one of the distinguishing aspects of BHLS in literature as well as in practice shows ambiguous relations in regression model. The relation with ridership can be either positive, negative or insignificant, depending on the region. For the reliability, only a slight negative relation for the cancellation rate is observed. This indicates that lines with a relatively high cancellation rate have lower ridership. No significant relations occurred for the punctuality. The strongest relation with ridership is observed for the frequency at the moment of travelling (i.e. Frequency 7:00h – 9:00h in the morning peak and Frequency 12:00h – 14:00h in the off-peak). There is a high correlation between the frequencies over the day. The availability could therefore not be included in the model while also including the frequency at the moment of travelling. Because including the frequency at the moment of travelling resulted in the highest R^2, the availability is not included in the models. The recognisability of the BHLS services does not show any relation with ridership. This goes for the label that is put on a service as well as for the deployment of BHLS vehicles. For the stop comfort, only shelters showed a positive relation with ridership. The presence of a DRIS panel or a bicycle parking facility do not have a significant relation. An overview of the findings can be found in Table 6.9.

Table 6.9 Conclusions regression analysis

Aspect	*Relation with ridership*	*Remark*
Speed	yes/no	If significant, can be either positive or negative
Reliability	yes/no	Only cancellation rate shows a significant relation
Frequency	yes	Strongest relation with ridership
Recognisability	no	Not significant in any model version
Stop design	yes/no	Only shelters show a significant relation

7 Impact of a dedicated BHLS fleet

In this chapter, the impact of a dedicated BHLS fleet is discussed. First, the impact on the operations is considered. After that, a framework is developed to estimate the costs of a dedicated BHLS fleet and how that should compare to ridership.

7.1 Impact on operations

This section discusses the impact of a dedicated BHLS fleet on the operational efficiency. Two aspects are considered for the operational efficiency. The first is the number of buses needed to run the timetable. The second is the vehicle deployment efficiency which is the in-service time divided by the total time including deadheading and turnaround times. The effect on the efficiency is worked out for two cases. The two cases consist of sets of vehicle schedules for different locations.

In both cases below, the considered buses are electric. Because of the limited electric range, the buses cannot be deployed for the entire day without charging. This means that buses need to go back to the depot during the day or need to be at a bus station with a charging facility for a longer time. This affects the operational efficiency. The results for the operational efficiency could be different if buses that run on fossil fuel were used.

7.1.1 Case 1: Lelystad – Nagele – Harderwijk

The first set of vehicle schedules is developed for eight lines that are carried out from three different depots: Lelystad, Nagele, and Harderwijk. Those lines consist of:

- 1 city line in Lelystad
- 3 regional lines
- 4 BHLS lines

The city line and the regional lines are *RRReis* services and the BHLS lines are *snelRRReis* services. In fact, more lines are carried out from the three depots. However, other vehicle types are used on those lines. Because of their technical differences, the vehicle types are not being exchanged and therefore these lines are not considered in this set of vehicle schedules.

For the *RRReis* and *snelRRReis* services, the same vehicle type is used (Ebusco 3.0). A dedicated BHLS fleet in this case only means that the BHLS buses have a different colour scheme on the outside. The technical aspects and capacity are identical for the conventional and BHLS fleet.

The required number of buses and the vehicle efficiency for the scenarios with one single fleet and with a dedicated fleet for the *snelRRReis* services can be found in Table 7.1

Table 7.1 Operational efficiency (case 1)

	One single fleet	*Dedicated BHLS fleet*
Number of buses	27	28
Vehicle in-service time	275:54 hours	275:54 hours
Total vehicle time	306:52 hours	307:26 hours
Vehicle efficiency	89.9%	89.7%

In this specific case, one additional bus is needed to run the weekday timetable with branded buses on the BHLS lines. In this specific case, one extra bus is an increase of 3.7% in the total number of buses. The vehicle in-service time is the same as the timetable is unchanged in the two scenarios. The scenario with a dedicated BHLS fleet has 32 minutes extra total vehicle time on a working day. This extra time is caused by at least one extra trip from and to the depot of the additional vehicle. Other potential sources of extra time are additional trips for charging and additional standstill. The exact source of all the extra time cannot be derived based on the information provided for this research.

7.1.2 Case 2: Apeldoorn

The second set of vehicle schedules is developed for the depot of Apeldoorn. From this depot, 20 lines are carried out. The share of BHLS lines of the total lines is substantially different from Case 1. Next to that, this case includes two different BHLS brandings compared to only one BHLS brand in Case 1. The lines carried out from Apeldoorn consist of:

- 14 city lines in Apeldoorn
- 2 regional lines
- 4 BHLS lines

The city lines and regional lines are *RRReis* services. The BHLS lines consist of three *snelRRReis* services and one *comfortRRReis* service. In the scenario where BHLS has its own dedicated fleet, three different fleets are needed because there are two different BHLS brands. The *RRReis* buses and *snelRRReis* buses are of the same vehicle type (BYD K9UB). *ComfortRRReis* buses are of another type (BYD K9UE). The electric performance of the *comfortRRReis* vehicles is slightly different form that of the vehicles for the *RRReis* and *snelRRReis* services. According to the schedule developer, this difference is neglectable in the development of the vehicle schedule (J. van Boldrik, personal conversation, May 22, 2025). This, in combination with the fact that the capacity of both vehicle types is very similar (39 versus 41 seats) makes a scenario with one single fleet technically and capacity wise feasible. If one of the services would have required for vehicles with a larger electric range or higher capacity, a scenario with one fleet for all services would not be possible.
The number of buses and the vehicle efficiency for the scenarios with and without a dedicated fleet for the BHLS services can be found in Table 7.2.

Table 7.2 Operational efficiency (case 2)

	One single fleet	*Dedicated BHLS fleets*
Number of buses	44	45
Vehicle in-service time	518:25 hours	518:25 hours
Total vehicle time	554:31 hours	557:36 hours
Vehicle efficiency	93.5%	93.0%

To have three different fleets for the different service types, one extra vehicle is needed. In this specific case, that is an increase of 2.3% in the total number of buses. The schedule developer observed that with a small timetable change, the number of needed buses in the scenario with one single fleet could be reduced to 43. However, for the sake of a fair comparison, the timetable is assumed to stay the same in both scenarios. The total vehicle time for the scenario with dedicated fleets increases with 3 hours and 5 minutes per working day. This causes the vehicle efficiency to drop with 0.5 percentage points. The decrease in vehicle efficiency is larger than in Case 1 but still relatively small. The increased time is, like in Case 1, caused by at least by one extra trip of the extra vehicle from and to the depot. The trip from and to the depot of the extra vehicle does not explain the full extra 3:05 hours of total vehicle time. Since there are fast charging facilities at Apeldoorn Station which is one of the terminal stations for most lines, it is unlikely that the rest of the extra time is caused by extra trips to the depot for charging. The most plausible explanation for the rest of the extra time is the need for longer turnaround times.

7.1.3 Conclusions examples

The two examples give a good first insight in the effect on the operations of a dedicated BHLS fleet. Despite the use of three instead of two fleets, the results in Case 2 are quite similar to the results in Case 1. In both cases, one extra vehicle is needed to run the BHLS services with a dedicated fleet which meant a fleet increase of 2.3 to 3.7%. Also, the vehicle efficiency decreases in both cases. The decrease in the vehicle efficiency is not extraordinary large. The difference in efficiency between the two cases is about 3%. The decrease of a dedicated fleet which is 0.2 and 0.5 percent points in Case 1 and 2 respectively falls within the margin of the variance across different locations.

It is important to note that the use of one single fleet is only possible when buses with the same (technical) characteristics can be used on all lines. In cases where BHLS lines for example require vehicles with a higher capacity or an extended electric range, it is not possible to run conventional and BHLS services with one single fleet. In such cases, the costs of a dedicated fleet cannot be avoided. Also, when an increased level of on-board comfort is offered on BHLS services, a separation in bus fleets is necessary. A good example of an on-board comfort increase can be seen in the BHLS buses of Qbuzz in concession area Zuid-Holland Noord. As extras over the conventional vehicles, BHLS vehicles for example have heated seats, tray tables, footrests, and adjustable headrests (see Figure 7.1).

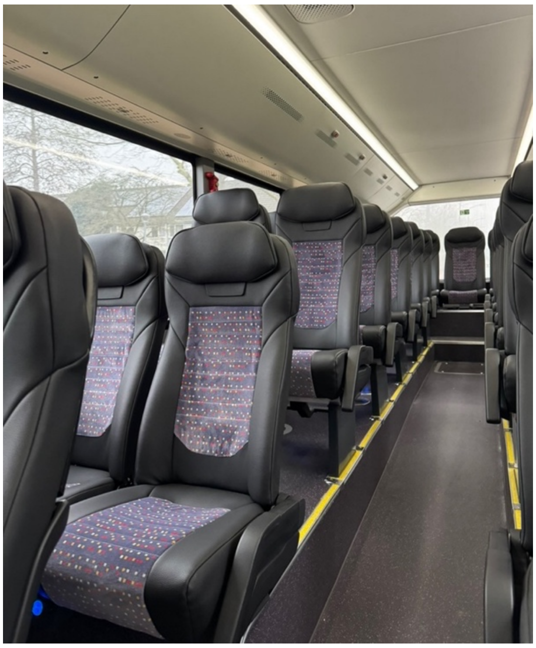

Figure 7.1 Luxurious R-net interior at Qbuzz

In the cases considered here, no different technical requirements where needed for the different lines. The difference in capacity between the *comfortRRReis* vehicles and *snelRRReis* and *RRReis* vehicles is neglected because the difference is very small. The slight comfort improvements of *comfortRRReis* vehicles as described in Chapter 4 are neglected too. It is upon the operator or transit authority if the compromises in capacity and comfort are acceptable.

7.2 Cost-effective BHLS fleet

The results from Chapter 6 showed that no relation between BHLS vehicle deployment and ridership can be proven. Therefore, the outcome of the application of the framework is known a priori. In the case study area, there is no proof for a ridership increase because of a dedicated BHLS fleet and therefore the costs are likely not to be covered by ridership increase.
Although the outcome is already known, there can still be lessons learned from applying the framework. Therefore, the framework to estimate the financial break-even point for a cost-effective BHLS fleet is still applied to the case study area. First, the costs of a dedicated BHLS fleet are computed based on the results from Section 7.1 and publicly available information. Then, the ridership increase that should be realised is estimated to cover those extra costs.

7.2.1 Costs of a dedicated BHLS fleet

With Equations 3.4 and 3.5, the ridership increase that should be realised to reach a break-even point for a cost-effective BHLS fleet can be computed.
The first parameter in the equation is the yearly depreciation of a bus. In 2016, an agreement (Bestuursakkoord Zero Emissie Regionaal Openbaar Vervoer Per Bus) was signed by the Dutch Ministry of Infrastructure and Environment and the transit authorities that as of 2025, all new buses should be CO_2 neutral (tank-to-wheel). For that reason, it is assumed that extra vehicles are battery electric buses. A standard electric bus costs about €500000 (Hooftman, et al., 2019; De Lijn, n.d.). Based on interviews with bus manufacturers and operators, Hooftman et al. (2019) state that an electric bus is depreciated to 10% of its original value in 10 years. This comes down to a depreciation of €450000 over a period of 10 years which is €45000 per year when assuming linear depreciation. The depreciation is multiplied with the extra number of buses needed which is only one in both considered cases.
The power consumption is selected as indicator for the vehicle operation cost. The costs related to the degradation of tires and brakes are assumed to be neglectable for the extra driven kilometres. The power consumption of the Ebusco buses is about 1.4 kWh/km (Ebusco, n.d.). The power consumption of the BYD buses is estimated to be 1.1 kWh/km based on the electric performance of a comparable vehicle type (BYD, n.d.). The energy price in the Netherlands is about €0.24 (excl. VAT) in Januari 2025 (NIBUD, 2025). Considering the average power consumption and energy price, the operation costs per kilometre are roughly €0.30.
From the information provided in the cases worked out above, it is impossible to determine the exact extra kilometres made in the scenario with a dedicated fleet. When determining the extra kilometres, it is assumed that the extra kilometres only consist of the trip of the extra bus from the depot to the closest terminal station and back. The distances vary per depot with a minimum of about 2 kilometres and a maximum of 12 kilometres for a round trip. Assuming that also one extra vehicle is needed during the

weekends for a dedicated BHLS service, the yearly extra distance driven is between 730 and 4380 kilometres.
For the labour costs, a gross hourly rate of €19 is used (based on the collective labour agreement salary of a driver with 5 years of experience). In this example, a surcharge of 40% is calculated for holiday pay, insurance contributions and pension contribution. The total labour costs per hour used in the calculation are €26.60.
The exact extra time bus drivers need to work cannot be derived from the information provided in the two cases. The extra labour hours are estimated to be only the time needed to drive the extra bus from the depot to the terminal station and back and the time to daily preparation and cleaning for the bus. The driving times vary between 4 and 16 minutes for a round trip. The preparation and daily cleaning of the bus are estimated to take about 10 minutes. The total extra labour time is thus between 14 and 26 minutes per day which is about 85 to 158 hours per year.
Now all individual parameters are known, the additional costs that come with a dedicated BHLS fleet can be computed. An overview of all input parameters can be found in Table 7.3. Since the number of extra kilometres and labour time are depot dependent, a lower bound (C_L) and an upper bound (C_H) are computed according to Equation 3.4.

Table 7.3 Cost parameters

Parameter	*Value*
Depreciation	45000 € / bus / year
Extra buses	1 bus
Vehicle operation costs	0.30 € / km
Extra kilometres	730 to 4380 km / year
Labour costs	26.60 € / hour
Extra labour	85 to 158 hours / year

$$C_L = 45{,}000 * 1 + 0.30 * 730 + 26.60 * 85 = €47{,}480.00$$
$$C_H = 45{,}000 * 1 + 0.30 * 4{,}380 + 26.60 * 158 = €50{,}516.80$$

The yearly costs are estimated to be between €47480 and €50517 for the two cases where one extra bus is needed. What stands out that a substantial part of the extra costs relates to the depreciation of the vehicles. In this case 89 to 95% of the total extra costs. Even in case diesel buses were used, which are generally about half as expensive as electric buses (De Lijn, n.d.), the depreciation would still have largest share in the total costs.

7.2.2 Ridership gains

To calculate the total number of extra passenger trips that should be made to cover the costs of a dedicated fleet, the average income per passenger must be estimated. In the Netherlands, ticket prices consist of a base fare and a kilometre fare. In the area of the two cases in 2024, the base fare was €0.99, and the kilometre fare was €0.18 (RRReis (2), n.d.). There was no supplement on the kilometre fare for BHLS services. In the Netherlands, a trip by bus, tram, or metro is on average 14.4 kilometres, based on 2023 numbers (CBS, n.d.). With this distance, the average income per trip is €3.58 (excl. VAT). Since also tram and metro trips are included in the average distance, the distance might be an underestimation of the distance travelled on the bus lines in the cases considered in this study. The actual average price per trip might thus be higher because people travel a longer distance. This especially goes for Case 1 where most

lines are regional lines. For simplicity, it is assumed that people traveling with discount make up for this underestimation of the trip distance and therefore, no correction terms are applied.
With the estimation of the average income per trip, the ridership gain that should be realised to reach a break-even point can be computed. This is computed for the lower bound (R_L) and the upper bound (R_H) of the costs following Equation 3.5.

$$R_L = \frac{47{,}480.00}{3.58} \approx 13{,}262\ trips/year$$

$$R_H = \frac{50{,}516.80}{3.58} \approx 14{,}111\ trips/year$$

In both the cases, 13262 to 14111 extra trips should be made because of the dedicated fleet. This ridership gain should in both cases be realised on the 4 BHLS lines. The deployment of branded vehicles on BHLS lines should not have any influence on ridership on conventional lines. The ridership gain should be about 10 passengers per BHLS line per day. Relative to the average number of daily passengers on the BHLS lines in the two cases, this increase is very small. The percentual increase should be about 1.3%.
In the computations in this section, a lot as assumptions are made. Therefore, the outcomes should be interpreted as rough estimations rather than exact solutions. The results are in line with the work of Finn, et al. (2011). In their work, they state that the use of a branding increases the investment and operation costs “a little bit”.
In the regression analysis in Chapter 6, there was no significant relation between the deployment of BHLS vehicles and ridership observed. Therefore, it is unlikely that a dedicated fleet leads to a ridership increase in this specific case study area. For the two specific cases described in this chapter, the advice would therefore be to use only one single fleet for all lines since the benefits of a dedicated fleet cannot be proven. However, it is also observed that a relatively small ridership increase could cover the extra costs of a dedicated fleet. Therefore, a small positive effect on ridership because of a dedicated fleet can already cover the extra costs. In Chapter 5, it was already discussed that BHLS buses are recognisable as a different service than conventional services because of their different look. However, also the remark was made that BHLS might not always be recognisable as a high-quality service. Next to that, the differences between conventional buses and BHLS buses are very limited apart from the colour scheme (see Chapter 4). A combination of a branding which is recognisable as high-quality and a BHLS fleet which is substantially more comfortable might lead to a small ridership increase which is needed to cover the costs of a dedicated fleet. This hypothesis should be tested in future work in a case study area where there are BHLS lines with a clear high-quality branding and luxurious BHLS buses.

7.3 Conclusions dedicated BHLS fleet

The two cases discussed in this chapter revealed that having a dedicated BHLS fleet negatively affects the operations. In the examples, the needed number of buses increases with 2.3 and 3.7%. Next to that, the vehicle deployment efficiency dropped with a few percentage points. This comes with costs which mainly consist of the depreciation of the extra vehicles that are needed. Because the increase in the number of vehicles and the impact on the efficiency is relatively small, only a small ridership increase could already cover the additional costs. In the examples from this chapter, an increase of about 10 passengers per BHLS line per day would already be enough for a cost-effective fleet.

The current application of the branding has no proven relation with ridership (see Chapter 6). To realise a cost-effective fleet, improvements in the BHLS fleet are likely to be needed. This could be done by improving the recognisability of the BHLS brandings and possibly by deploying more luxurious vehicles to improve the on-board experience.

8 Conclusions and recommendations

In this chapter, the research questions are answered based on the finding throughout the report. Next to that, the limitations of this work are discussed in Section 8.2. Finally, recommendations for future research are given in Section 8.3.

8.1 Answer to the research questions

This section step-by-step answers the sub-questions as formulated in Section 1.3 to in the end answer the main research question.

1. *What are relevant aspects that distinguish BHLS bus services from conventional bus services according to literature?*

In the literature review in Chapter 2, a number of aspects are found that characterise BHLS. Based on those aspects, six targets are defined to easily explain what BHLS should be. Those targets are:

- Fast because of a low stop density and dedicated road infrastructure
- Reliable because of dedicated road infrastructure
- Frequent
- Recognisable because of a dedicated identity
- Available due to wide exploitation hours
- Comfortable because of a good stop design, dynamic traveller information, and a high in-vehicle seat availability

2. *How does the performance of BHLS services compare to the performance of conventional bus services on BHLS aspects?*

In the case study area as described in Chapter 4, conventional and BHLS services are assessed on their performance on the BHLS characteristics as found while answering the first sub-question. The performances of the two service types are compared in Chapter 5. The results reveal that compared to conventional bus services:

- BHLS has a higher operational speed
- BHLS is not more reliable regarding punctuality and cancellations
- BHLS is more frequent
- BHLS has a better availability outside the peak hours
- BHLS has a distinguishing branding
- BHLS is not always more comfortable regarding stop comfort
- BHLS is not more comfortable regarding seat availability

3. *What is the relation between individual BHLS aspects and ridership?*

Out of all BHLS aspects, the frequency has the strongest relation with ridership in the case study area. More frequent services have higher ridership. Next to that, also a significant relation with the operational speed is found in some of the concession areas. However, against expectations, the relation with the operational speed is negative in Zaanstreek-Waterland. The negative relation can possibly be explained by the population density of the areas the bus goes through. In IJssel-Vecht, a positive relation with the operational speed is observed, but only in the off-peak model. In the

MRDH, no significant relation is found. Because the relation of the speed with ridership is not consistent over the different concession areas, no general conclusions can be drawn. The share of stops with a shelter along the route shows a positive relation with ridership. The other two stop design features do not show a significant relation with the number of passengers. This can possibly be explained by the fact that there are online alternatives for DRIS panels and bicycle parking facilities are only relevant for passengers using the bicycle as access or egress mode. The reliability does not have a strong relation with ridership. Only in the off-peak model, a relatively small negative relation is observed indicating that lines with a high cancellation rate have lower ridership. During the morning peak, this relation is not significant. Punctuality, which is the other aspect of reliability, does not show any relation with ridership. Classifying services as BHLS and giving them a different name has also not proven to have any effect on ridership in the case study area. There is also no relation between the deployment of (recognisable) BHLS vehicles and ridership observed. Three hypothetical explanations for this are that passengers do not recognise BHLS brands as a high-quality brand, incorrect vehicle deployment, and an inconsistent performance of BHLS services (in relation to conventional services).

4. *What is the impact of deploying dedicated BHLS vehicles on the operational efficiency?*

In both considered cases for different depots, one extra bus was needed to have a dedicated BHLS fleet. This is a 2.3 to 3.7% increase over the number of buses needed in case of one single fleet for all lines. It was observed that with some small changes to optimise the table for a specific scenario the difference in the number of buses needed could become larger.
Next to the number of buses needed, also the efficiency of the vehicle deployment is affected by the separation in fleets. However, the decrease in efficiency due to a dedicated fleet is only a few tenths of a percent. This is considered to fall within the margins of the efficiency differences observed between different depots.

5. *What does a framework look like to estimate the required ridership gains to reach a break-even point for a cost-effective BHLS fleet?*

Now that it is known that a separate BHLS fleet affects the operational efficiency, it is valuable to estimate what the ridership gains should be to make the fleet cost-effective. An indication the break-even point in terms of ridership increase can help in the decision making about the implementation of a BHLS fleet. The break-even point is estimated based on the yearly costs of a dedicated fleet and the average income per trip. The costs of a dedicated fleet consist of the depreciation of the extra vehicles, costs related to the additional kilometres, and the extra labour hours related to the deployment of extra vehicles. The income per passenger can be estimated based on the fares in combination with the average trip distance.
With the information from the answer to sub-question 4, the framework is applied to the case study area. The key takeaways for the application are that the main costs consist of the depreciation of the extra required bus and the required ridership gains is relatively small. The ridership increase required for a cost-effective fleet in the case study area is estimated to be around 1.3%.

MRQ: Which aspects of BHLS are most critical when upgrading conventional bus services to gain ridership while considering the operational efficiency?

BHLS has many aspects according to the literature. In the case study area, not all of these aspects always come into play. When considering the relation between different aspects of BHLS and ridership, it is not necessarily a problem that not all aspects are put to practice. The regression analysis has shown that only improvements in frequency, share of stops with a shelter and cancellation rate have a relation with ridership increase. Therefore, those are the three most critical aspects to incorporate when upgrading conventional bus services regarding ridership gains. There are no convincing positive relations with ridership observed for the speed, punctuality, recognisability, bicycle parking facilities, and DRIS panels. Those aspects are less likely to affect ridership and are thus less critical when upgrading conventional bus services. This does not mean that they can completely be neglect. As discussed in Chapter 6, it cannot be ruled out that there are some indirect effects on ridership through improvement of the overall image of BHLS.

8.2 Limitations

There are some limitations to the method and resources used for this work. This section reflects on these limitations.

8.2.1 Data quality

The most self-evident point of discussion for a data driven study is the quality of the data. For this study, many different types of data from different sources are used. The two most pronounced data types are AVL and AFC data. In November 2024, about 5% of the trips was not registered causing missing AVL data. Since data for an entire month is collected, there are still a lot of trips per line included in the analysis and thus the impact of missing trips is likely to be very limited. Next to that, there are some outliers in the AVL data indicating for example extreme delays or early departures. Visual plots showed that the number of outliers is very small and therefore the impact on the analyses is considered small. Besides that, extreme values do not have a large impact on punctuality analysis because the magnitude of early arrivals and delays is not relevant in the CROW punctuality definition.

It is unknown how much passenger data is missing because of incomplete AFC data. The data can be incomplete because of malfunctioning card readers or passengers forgetting to tap in or out. The effect of missing data is likely to be small considering the size of the dataset. Another shortcoming of the AFC data is that individually bought barcode tickets are not included in the data because they cannot be assigned to specific trips. In regional public transport, about 83% of the payments in 2024 were made with the OV-Chipkaart (smart card) and another 15% with OV Pay (tap in and out using a bank card) (CROW, 2024). These two payment methods are included in the AFC data and therefore the impact of missing barcode tickets is considered neglectable.

Overall, it can be concluded that the quality of the data is not perfect, like is generally the case for real world data sets. However, the effects of missing data or wrong data are considered to be very limited.

8.2.2 Regression and causality

In this work, the relations between BHLS characteristics and ridership are investigated. It is important to note that a significant relation does not prove causality. The fact that ridership is higher on lines with a high frequency does not necessarily mean that a high frequency causes high ridership. By inserting all predictor variables in one multiple regression model, the chance of finding a relation whilst another predictor variables are causing the effect is reduced. However, external factors play a role in ridership too. Next to that, the regression model does not give insight about how the interaction between BHLS aspects and ridership works. For example, it is unknown whether ridership increases because there are more shelters along a line or whether the infrastructure manager places more shelters along lines with higher ridership.
On the other hand, if there is no significant relation observed, it does not have to mean that there is absolutely no impact on ridership possible. As discussed before, people might not base their mode choice based on the performances of a single line but more on a general image of buses. In this way, the performance of individual lines may not show a significant relation with ridership although the average performance does contribute to an improvement of the overall image of bus transit.

8.2.3 External factors

Lastly, external factors play an important role in ridership. To avoid overfitting, these factors are not included in the regression model. The most important external factors might be the ones relating to demand. Examples of such external factors are population and job density. Of course, ridership will never be high on bus lines that do not serve in regions with points of interest, regardless of the performance of the bus service. The issue with these external factors is that they should be determined on a very local (neighbourhood-like) scale which costs a lot of computational effort.
In the case study area, (demand related) external factors are excluded from the model. Although there are differences between the lines. None of the lines serve solely between very small towns and none of them only in the central business district of a large agglomeration. Therefore, the choice to exclude these factors is considered justifiable.

8.3 Recommendations for operators and authorities

Operators and transit authorities can use the knowledge from this work to develop an effective strategy for upgrading conventional bus services. This section gives advice on each of the BHLS aspects considered in this work.
The comparison between conventional services and BHLS has shown that a high frequency is already featured in existing BHLS services. Based on the findings in this report, this should be sustained or even further improved to at least six buses per hour per direction. A high frequency should have priority when upgrading conventional services as it has a strong relation with ridership.
Stops along BHLS lines are not always more comfortable compared to stops along conventional lines. A strong relation between the share of stops with a shelter and ridership is observed. There are no significant relations with ridership observed for bicycle parking facilities and DRIS panels. Therefore, it is recommended to prioritise placing shelters when upgrading bus stops.
Reliability was found to be an important aspect of BHLS in the literature review. However, there was no significant relation found between the punctuality and ridership. When it comes to cancellation rates, a small but significant relation between lowering

the cancellation rate and ridership is observed. The reliability of all considered service types in the case study area is quite good in an international perspective. The high reliability should be maintained. When improving the reliability, the advice would be to focus on minimising cancellations.

The operational speed is a more difficult aspect to give advice on. Significant relations with ridership are observed although these are not necessarily positive. As discussed in Section 6.4, a negative relation with the operational speed could be caused by external effects and does not automatically mean that passengers dislike a high operational speed. As higher operational speeds can make the bus more competitive in travel time to other modes, improving the speed can be beneficial to attract more passengers. Therefore, improvements in the operational speed are recommended despite the negative relations in some specific cases. However, improvements in the operational speed show have a lower priority than for example the frequency.

Lastly, this report starts with the observation that many Dutch bus operators have at least one dedicated brand name for their BHLS services. This observation is confirmed in Chapter 5 by showing that all BHLS lines in the case study area are by default carried out by branded vehicles. However, there is no significant relation found between the recognisability of BHLS and ridership. Examples in Chapter 7 show that having a recognisable BHLS fleet requires extra buses and negatively impacts the operational efficiency. Since the necessary increase in ridership to cover the costs is relatively low, a separation in bus fleets is not by definition dissuaded. Based on the case study data, it cannot be proved that a different brand name with a distinguishable colour scheme on its own is enough to realise this increase. Future research should reveal whether a clear brand name which is recognisable as high-quality, consistent application of the brand, and an improved level of comfort on the BHLS buses could be steps towards improving the profitability of a BHLS fleet.

8.4 Recommendations for future work

While looking for the answers to the research questions in this work, new questions raised up which could be answered in follow up studies. In Chapter 6, no significant relation between the deployment of BHLS vehicles and ridership was observed. Three hypotheses why this is not the case could be tested in future works. The first hypothesis is that the *R-net* branding is not recognisable as a high-quality. A survey-based study could give valuable insights in the recognisability of *R-net* which help clarifying the absence of a relation with ridership. Secondly, it is questionable whether the choice to label a bus line as BHLS is always justifiable. It is assumed that an inconsistent application of the brand name may impact the recognisability of BHLS brands as high-quality. A study in which a framework is developed to assess whether a line should be classified as BHLS or not could help operators and authorities to consistently use BHLS branding. Lastly, the limited – or sometimes non-existing – improvements in the on-board comfort on BHLS services might be a reason why there is a relation observed between the BHLS vehicle deployment and ridership. A study into the effect of the deployment of luxurious BHLS buses on ridership should be conducted to test this hypothesis.

Next, in order to get a better understanding about the causality between BHLS aspects and ridership, a before-after study could be conducted. This could be a long-term study where ridership is closely monitored before and in the years after upgrading the performance on one of the BHLS aspects. The results of this study can help developing a targeted approach to investigating causalities.

The final recommendation for future work is to extend this work with additional data and factors that affect ridership. Part of this could be incorporating external factors relating to the demand. This can lead to even more reliable results and a deeper understanding of all existing relations. It is important to realise that adding more variables will also require a larger sample size to avoid overfitting.

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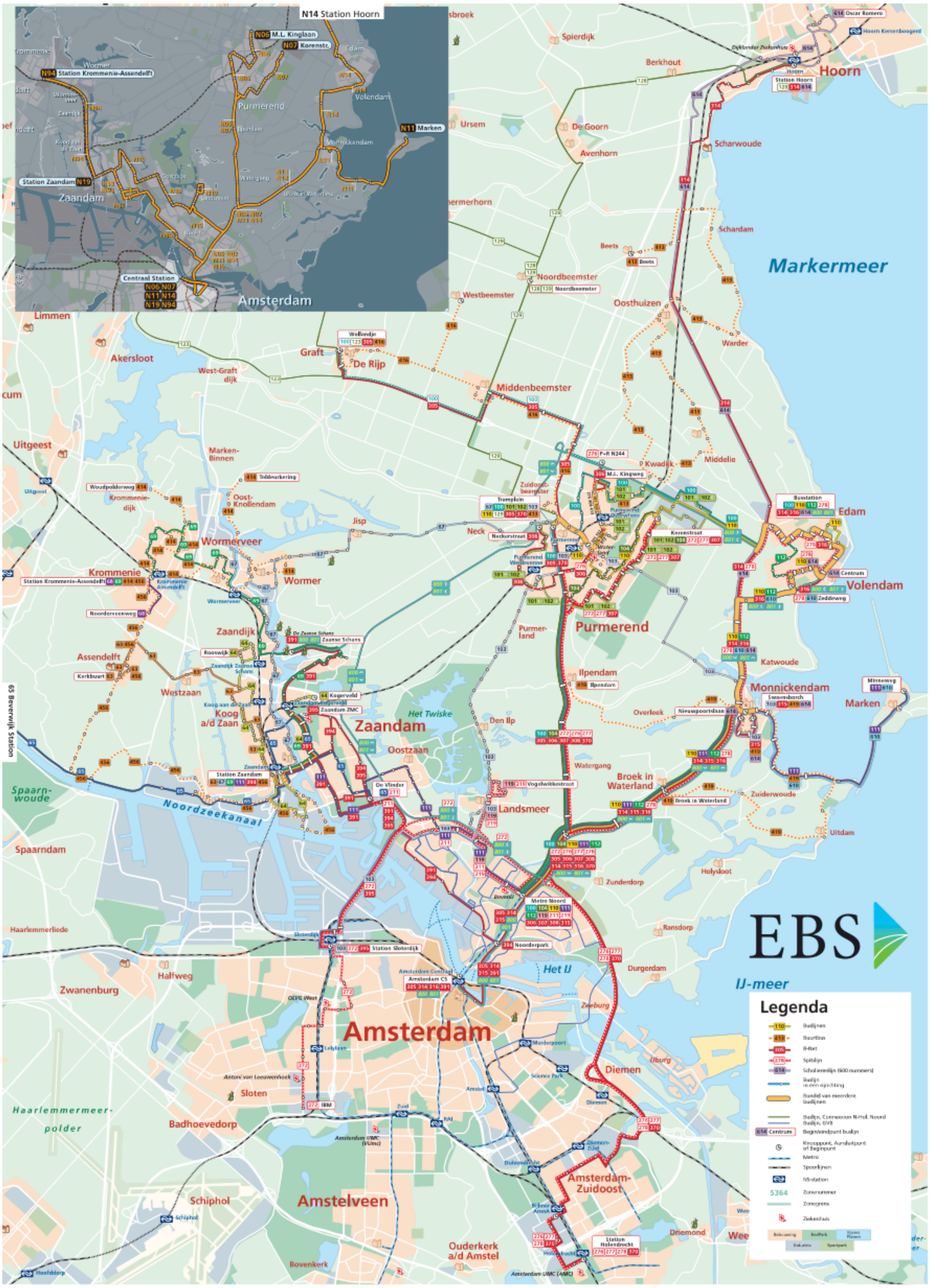
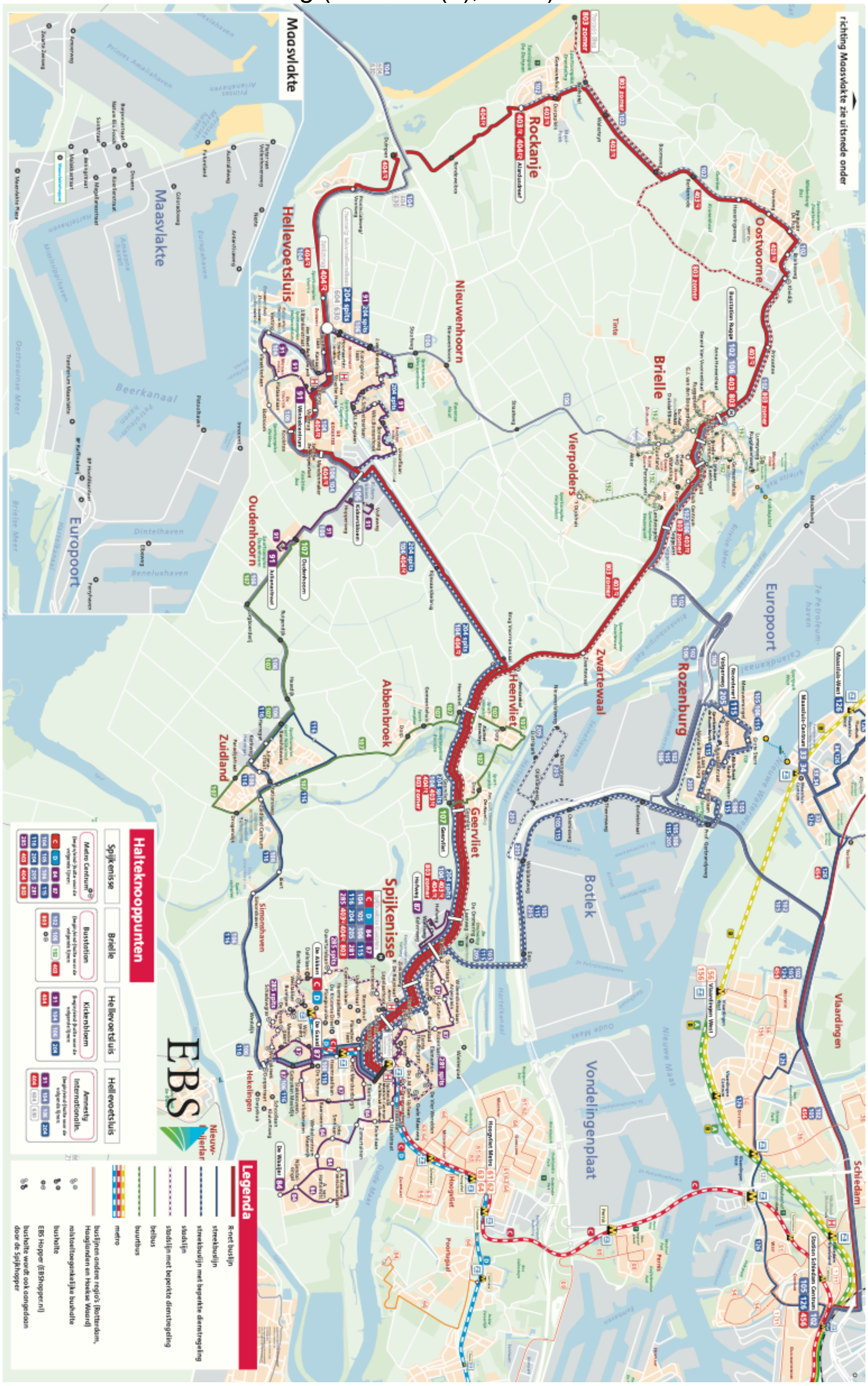
Appendix A Network maps EBS

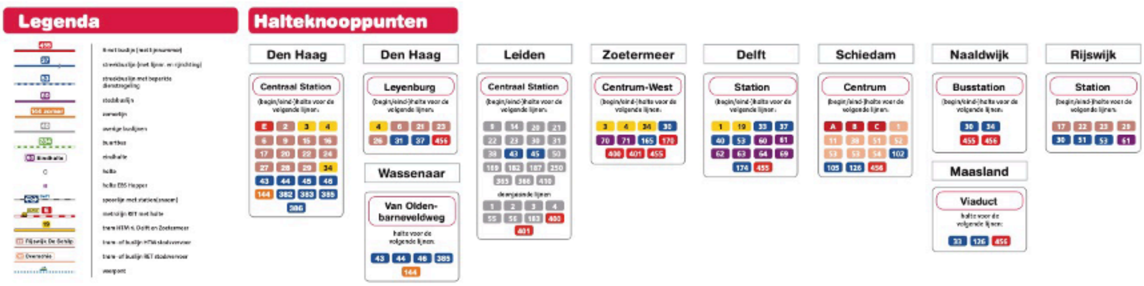
Zaanstreek – Waterland (EBS OV (1), 2024)



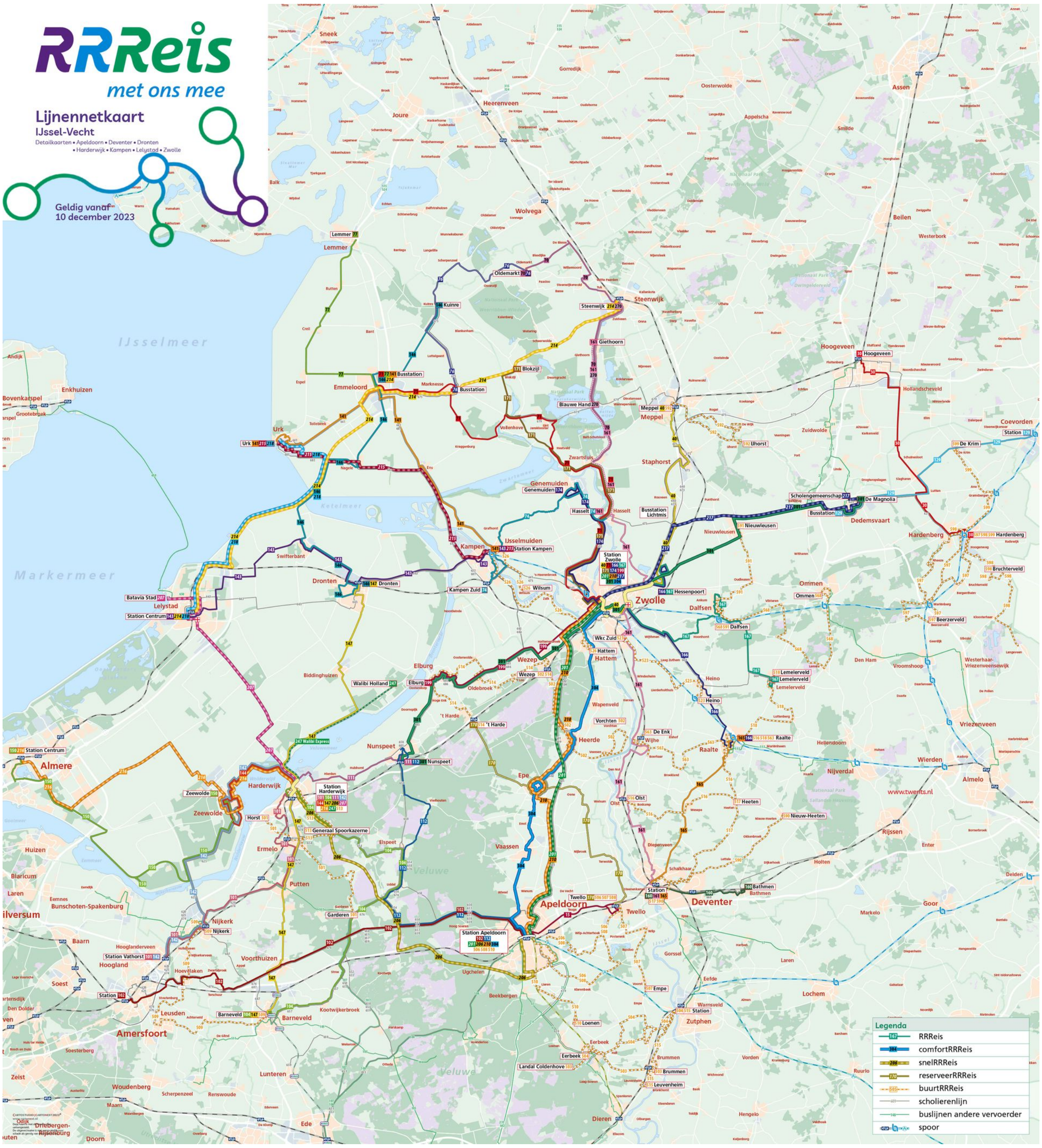
Voorne-Putten Rozenburg (EBS OV (1), 2024)



Haaglanden (EBS OV (1), 2024)



IJssel-Vecht (RRReis (3), n.d.)



Appendix B Comparison details

This appendix supports the results reported in Chapter 5. In this appendix, the off-peak comparison figures are displayed for aspects where the comparison is applicable. Next to that, the exact numbers behind the comparison figures and their standard deviations are reported. Also, the results from the t-test can be found in this appendix.

Operational Speed

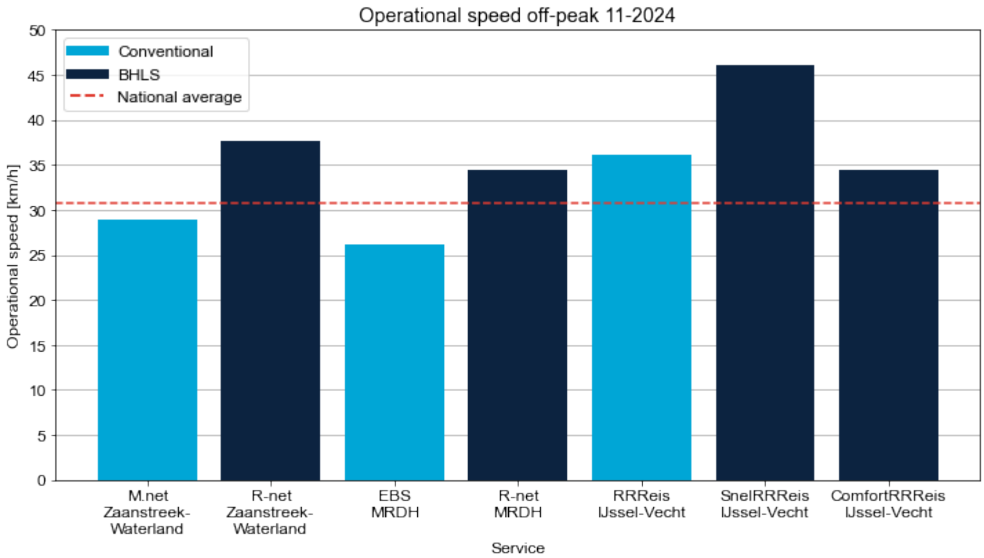


Figure B.1 Operational speed per service (off-peak)

Table B.1 Descriptive statistics operational speed

Service	***7:00h – 9:00h***		***12:00h – 14:00h***	
	Mean [km/h]	**SD**	**Mean [km/h]**	**SD**
M.net Zaanstreek-Waterland	29.49	5.96	28.95	6.09
R-net Zaanstreek-Waterland	37.26	7.05	37.68	7.17
EBS MRDH	25.39	4.00	26.23	4.64
R-net MRDH	33.64	4.96	34.48	5.56
RRReis IJssel-Vecht	36.57	4.74	36.15	4.82
snelRRReis IJssel-Vecht	45.39	4.64	46.02	4.86
comfortRRReis IJssel-Vecht	33.07	0.13	34.41	0.59

Table B.2 t-test results operational speed

Time	***Region***	***Conventional***	***BHLS***	***Deg. of freedom***	***t-test result***	***p-value***
7:00h – 9:00h	Zaanstreek-Waterland	*M.net*	*R-net*	21	2.87	0.009
	MRDH	*EBS*	*R-net*	15	3.34	0.004
	IJssel-Vecht	*RRReis*	*snelRRReis*	30	4.58	0.000
	IJssel-Vecht	*RRReis*	*comfortRRReis*	*		
12:00h – 14:00h	Zaanstreek-Waterland	*M.net*	*R-net*	21	3.15	0.005
	MRDH	*EBS*	*R-net*	15	2.98	0.009
	IJssel-Vecht	*RRReis*	*snelRRReis*	27	4.71	0.000
	IJssel-Vecht	*RRReis*	*comfortRRReis*	23	-0.62	0.544

*No statistical test due to small sample size and unequal variances: d = -0.74

Punctuality

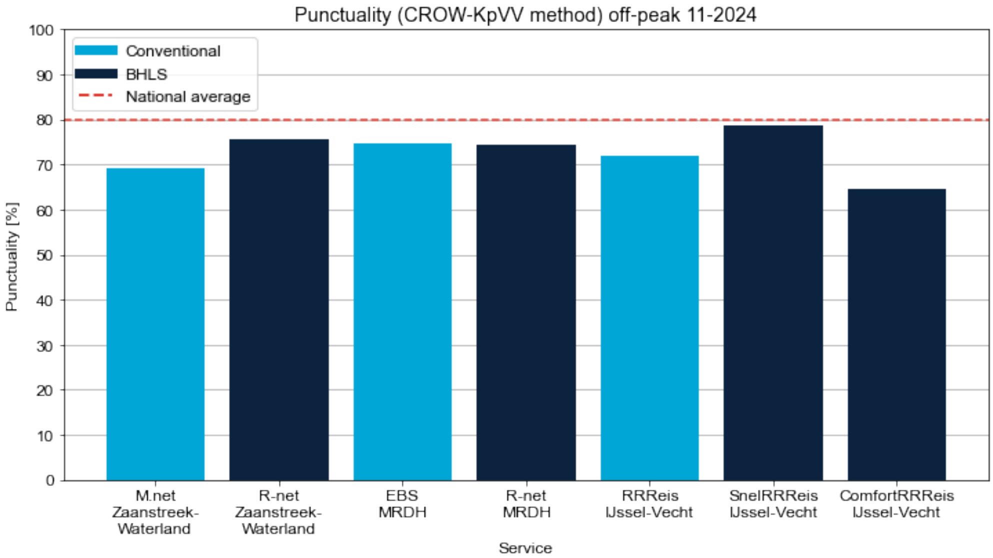


Figure B.2 Punctuality per service (off-peak)

Table B.3 Descriptive statistics punctuality

Service	***7:00h – 9:00h***		***12:00h – 14:00h***	
	Mean [%]	**SD**	**Mean [%]**	**SD**
M.net Zaanstreek-Waterland	65.86	8.19	69.30	9.98
R-net Zaanstreek-Waterland	69.17	8.74	75.65	8.94
EBS MRDH	72.48	6.76	74.69	8.17
R-net MRDH	72.55	4.02	74.34	3.26
RRReis IJssel-Vecht	69.11	8.61	71.89	11.25
snelRRReis IJssel-Vecht	78.54	8.43	78.82	7.40
comfortRRReis IJssel-Vecht	72.55	7.57	64.50	5.80

Table B.4 t-test results punctuality

Time	***Region***	***Conventional***	***BHLS***	***Deg. of freedom***	***t-test result***	***p-value***
7:00h – 9:00h	Zaanstreek-Waterland	*M.net*	*R-net*	21	0.94	0.359
	MRDH	*EBS*	*R-net*	15	0.02	0.985
	IJssel-Vecht	*RRReis*	*snelRRReis*	30	2.70	0.011
	IJssel-Vecht	*RRReis*	*comfortRRReis*	25	0.66	0.516
12:00h – 14:00h	Zaanstreek-Waterland	*M.net*	*R-net*	21	1.60	0.124
	MRDH	*EBS*	*R-net*	15	-0.08	0.936
	IJssel-Vecht	*RRReis*	*snelRRReis*	27	1.52	0.141
	IJssel-Vecht	*RRReis*	*comfortRRReis*	23	-1.10	0.282

Cancelled kilometres

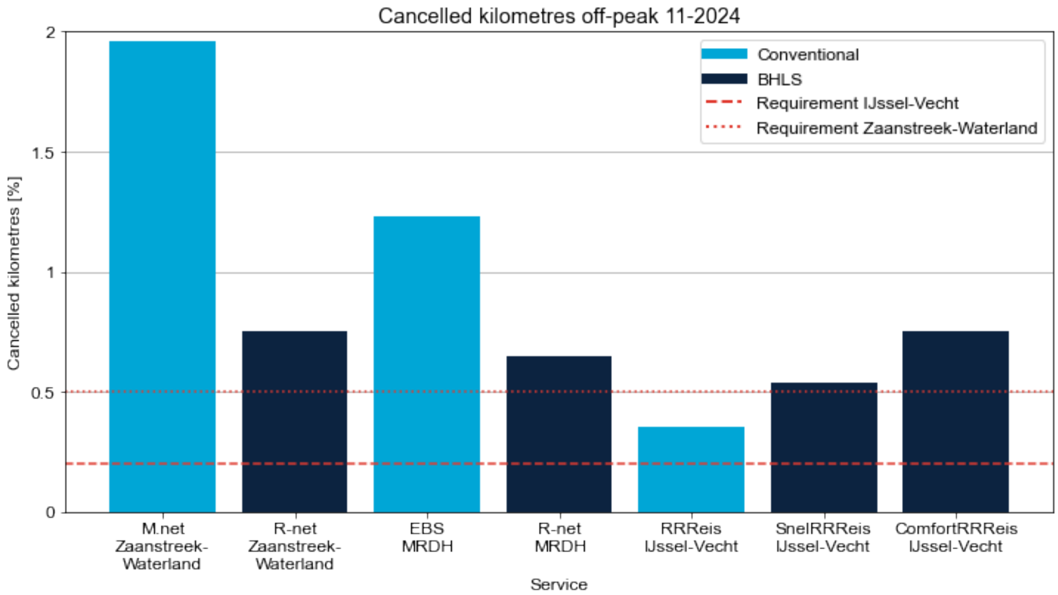


Figure B.3 Cancelled kilometres per service (off-peak)

Table B.5 Descriptive statistics cancelled kilometres

Service	***7:00h – 9:00h***		***12:00h – 14:00h***	
	Mean [%]	**SD**	**Mean [%]**	**SD**
M.net Zaanstreek-Waterland	4.99	3.42	1.96	2.99
R-net Zaanstreek-Waterland	3.64	1.37	0.75	0.73
EBS MRDH	1.39	1.32	1.23	1.12
R-net MRDH	2.23	1.16	0.65	0.56
RRReis IJssel-Vecht	0.53	0.93	0.35	0.85
snelRRReis IJssel-Vecht	0.00	0.00	0.54	0.88
comfortRRReis IJssel-Vecht	0.25	0.24	0.75	0.65

Table B.6 t-test results cancelled kilometres

Time	***Region***	***Conventional***	***BHLS***	***Deg. of freedom***	***t-test result***	***p-value***
7:00h – 9:00h	Zaanstreek-Waterland	*M.net*	*R-net*	14.72	-1.26	0.226
	MRDH	*EBS*	*R-net*	15	1.14	0.270
	IJssel-Vecht	*RRReis*	*snelRRReis*	30	-1.59	0.123
	IJssel-Vecht	*RRReis*	*comfortRRReis*	25	-0.51	0.615
12:00h – 14:00h	Zaanstreek-Waterland	*M.net*	*R-net*	21	-1.30	0.207
	MRDH	*EBS*	*R-net*	15	-0.98	0.340
	IJssel-Vecht	*RRReis*	*snelRRReis*	27	0.51	0.615
	IJssel-Vecht	*RRReis*	*comfortRRReis*	23	0.78	0.444

Frequency

Table B.7 Descriptive statistics frequency

Unit frequency: buses per hour per direction

Service	7:00h – 9:00h		12:00h – 14:00h		19:00h– 21:00h	
	Mean	SD	Mean	SD	Mean	SD
M.net ZaWa	3.19	1.41	2.33	0.78	2.04	1.01
R-net ZaWa	5.77	0.21	3.93	0.71	3.36	0.97
EBS MRDH	2.75	1.25	2.44	0.74	1.63	0.67
R-net MRDH	5.31	1.43	4.06	0.12	2.56	0.72
RRReis IJV	1.59	0.46	1.24	0.41	0.76	0.54
snelRRReis IJV	2.09	0.72	1.31	0.65	0.50	0.46
comfortRRReis IJV	4.08	0.14	2.25	0.25	2.00	0.00

Table B.8 t-test results frequency

Time	Region	Conventional	BHLS	Deg. of freedom	t-test result	p-value
7:00h – 9:00h	Zaanstreek-Waterland	*M.net*	*R-net*	11.52	6.27	0.000
	MRDH	*EBS*	*R-net*	15	3.49	0.003
	IJssel-Vecht	*RRReis*	*snelRRReis*	30	2.31	0.028
	IJssel-Vecht	*RRReis*	*comfortRRReis*	25	9.19	0.000
12:00h – 14:00h	Zaanstreek-Waterland	*M.net*	*R-net*	21	5.14	0.000
	MRDH	*EBS*	*R-net*	15	4.24	0.001
	IJssel-Vecht	*RRReis*	*snelRRReis*	30	0.78	0.443
	IJssel-Vecht	*RRReis*	*comfortRRReis*	25	3.57	0.001
19:00h – 21:00h	Zaanstreek-Waterland	*M.net*	*R-net*	21	3.19	0.004
	MRDH	*EBS*	*R-net*	15	2.40	0.030
	IJssel-Vecht	*RRReis*	*snelRRReis*	30	-1.21	0.235
	IJssel-Vecht	*RRReis*	*comfortRRReis*	25	3.88	0.001

Stop Comfort

Table B.9 Descriptive statistics stop design

Service	Shelter		Bicycle parking		Dynamic passenger information	
	Mean [%]	SD	Mean [%]	SD	Mean [%]	SD
M.net ZaWa	69.63	14.72	47.53	26.12	48.30	13.87
R-net ZaWa	88.22	11.72	74.86	17.28	63.18	15.19
EBS MRDH	76.26	15.46	49.51	19.15	61.24	26.49
R-net MRDH	90.94	3.84	60.59	3.57	77.46	4.39
RRReis IJV	52.02	17.97	40.75	15.07	10.95	9.34
snelRRReis IJV	77.55	15.10	58.34	9.86	26.13	22.25
comfortRRReis IJV	67.53	13.86	66.56	6.18	28.91	15.39

Table B.10 t-test results stop design

Aspect	Region	Conventional	BHLS	Deg. of freedom	t-test result	p-value
Shelter	Zaanstreek-Waterland	*M.net*	*R-net*	21	3.38	0.003
	MRDH	*EBS*	*R-net*	15	1.84	0.085
	IJssel-Vecht	*RRReis*	*snelRRReis*	30	3.61	0.001
	IJssel-Vecht	*RRReis*	*comfortRRReis*	25	1.43	0.164
Bicycle parking	Zaanstreek-Waterland	*M.net*	*R-net*	21	2.98	0.008
	MRDH	*EBS*	*R-net*	15	1.13	0.278
	IJssel-Vecht	*RRReis*	*snelRRReis*	30	3.07	0.004
	IJssel-Vecht	*RRReis*	*comfortRRReis*	25	2.89	0.008
DRIS	Zaanstreek-Waterland	*M.net*	*R-net*	21	2.46	0.023
	MRDH	*EBS*	*R-net*	*		
	IJssel-Vecht	*RRReis*	*snelRRReis*	7.84	1.87	0.099
	IJssel-Vecht	*RRReis*	*comfortRRReis*	25	2.94	0.007

*No statistical test due to small sample size and unequal variances: d = 0.61

Seat availability

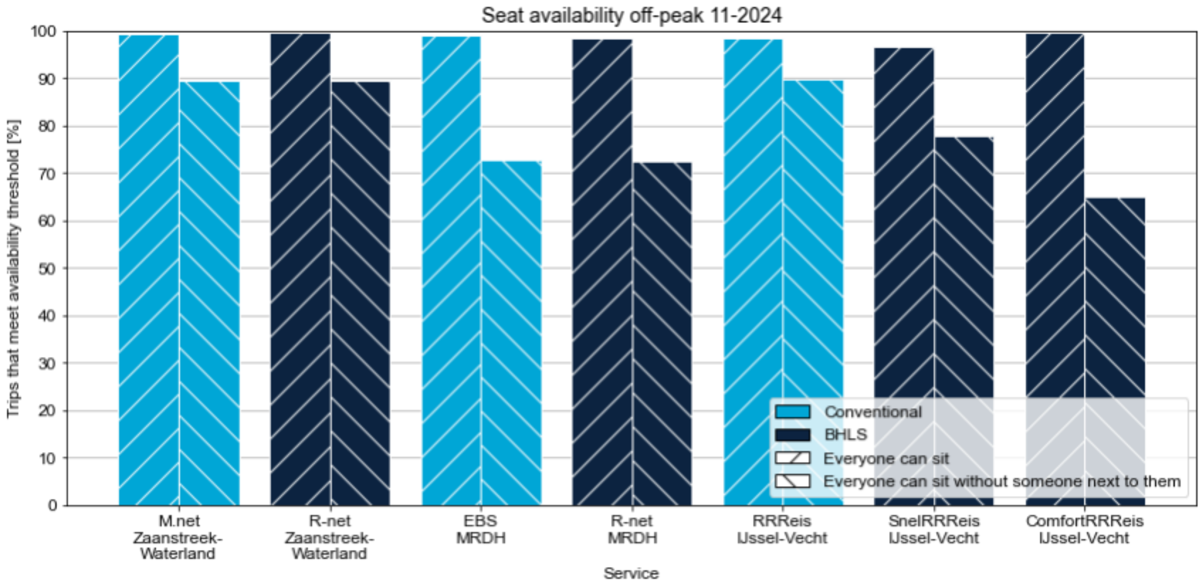


Figure B.4 Seat availability per service (off-peak)

Table B.11 Descriptive statistics occupancy ≤ 100 percent

Service	***7:00h – 9:00h***		***12:00h – 14:00h***	
	Mean [%]	**SD**	**Mean [%]**	**SD**
M.net Zaanstreek-Waterland	94.74	5.32	99.43	1.35
R-net Zaanstreek-Waterland	90.49	5.06	99.57	0.79
EBS MRDH	87.35	12.29	99.16	1.30
R-net MRDH	87.72	11.76	98.30	2.08
RRReis IJssel-Vecht	94.78	6.33	98.43	5.24
snelRRReis IJssel-Vecht	92.74	9.14	96.56	6.70
comfortRRReis IJssel-Vecht	96.67	3.01	99.56	0.38

Table B.12 t-test results occupancy ≤ 100 percent

Time	***Region***	***Conventional***	***BHLS***	***Deg. of freedom***	***t-test result***	***p-value***
7:00h – 9:00h	Zaanstreek-Waterland	*M.net*	*R-net*	21	-1.96	0.064
	MRDH	*EBS*	*R-net*	15	0.05	0.958
	IJssel-Vecht	*RRReis*	*snelRRReis*	30	-0.70	0.487
	IJssel-Vecht	*RRReis*	*comfortRRReis*	25	0.50	0.619
12:00h – 14:00h	Zaanstreek-Waterland	*M.net*	*R-net*	21	0.29	0.778
	MRDH	*EBS*	*R-net*	15	-1.01	0.328
	IJssel-Vecht	*RRReis*	*snelRRReis*	27	-0.77	0.447
	IJssel-Vecht	*RRReis*	*comfortRRReis*	23	0.37	0.718

Table B.13 Descriptive statistics occupancy ≤ 50 percent

Service	7:00h – 9:00h		12:00h – 14:00h	
	Mean [%]	SD	Mean [%]	SD
M.net Zaanstreek-Waterland	71.29	13.51	89.42	9.78
R-net Zaanstreek-Waterland	63.07	7.73	89.50	9.92
EBS MRDH	49.00	26.00	72.82	23.23
R-net MRDH	40.39	26.47	72.58	16.08
RRReis IJssel-Vecht	76.24	18.88	89.86	16.31
snelRRReis IJssel-Vecht	64.02	22.43	77.84	20.68
comfortRRReis IJssel-Vecht	70.48	12.09	65.11	17.12

Table B.14 -test results occupancy ≤ 50 percent

Time	*Region*	*Conventional*	*BHLS*	*Deg. of freedom*	*t-test result*	*p-value*
7:00h – 9:00h	Zaanstreek-Waterland	*M.net*	*R-net*	21	-1.77	0.092
	MRDH	*EBS*	*R-net*	15	-0.58	0.958
	IJssel-Vecht	*RRReis*	*snelRRReis*	30	-1.51	0.140
	IJssel-Vecht	*RRReis*	*comfortRRReis*	25	-0.51	0.614
12:00h – 14:00h	Zaanstreek-Waterland	*M.net*	*R-net*	21	0.02	0.984
	MRDH	*EBS*	*R-net*	15	-0.02	0.985
	IJssel-Vecht	*RRReis*	*snelRRReis*	27	-1.59	0.123
	IJssel-Vecht	*RRReis*	*comfortRRReis*	23	-2.45	0.022

Appendix C Regression 7:00h – 9:00h

This appendix contains the IBM SPSS Statistics output tables of the base model and the model with regional coefficients for the morning peak.

Base model

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.725[a]	.526	.519	3711.388
2	.762[b]	.580	.569	3516.172
3	.788[c]	.621	.605	3363.625
4	.833[d]	.693	.676	3049.054
5	.850[e]	.722	.702	2923.396

a. Predictors: (Constant), Frequency 7:00h – 9:00h

b. Predictors: (Constant), Frequency 7:00h – 9:00h, Speed

c. Predictors: (Constant), Frequency 7:00h – 9:00h, Speed, Shelter

d. Predictors: (Constant), Frequency 7:00h – 9:00h, Speed, Shelter, Stops

e. Predictors: (Constant), Frequency 7:00h – 9:00h, Speed, Shelter, Stops, Cancelled kilometres

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1115407979	1	1115407979	80.977	<.001[b]
	Residual	1005531374	73	13774402.4		
	Total	2120939353	74			
2	Regression	1230769842	2	615384921	49.774	<.001[c]
	Residual	890169511	72	12363465.4		
	Total	2120939353	74			
3	Regression	1317647481	3	439215827	38.821	<.001[d]
	Residual	803291873	71	11313970.0		
	Total	2120939353	74			
4	Regression	1470168243	4	367542061	39.535	<.001[e]
	Residual	650771110	70	9296730.142		
	Total	2120939353	74			
5	Regression	1531248631	5	306249726	35.834	<.001[f]
	Residual	589690723	69	8546242.360		
	Total	2120939353	74			

a. Dependent Variable: #passengers

b. Predictors: (Constant), Frequency 7:00h – 9:00h

c. Predictors: (Constant), Frequency 7:00h – 9:00h, Speed

d. Predictors: (Constant), Frequency 7:00h – 9:00h, Speed, Shelter

e. Predictors: (Constant), Frequency 7:00h – 9:00h, Speed, Shelter, Stops

f. Predictors: (Constant), Frequency 7:00h – 9:00h, Speed, Shelter, Stops, Cancelled kilometres

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-274.288	866.743		-.316	.753
	Frequency 7:00h - 9:00h	2249.826	250.016	.725	8.999	<.001
2	(Constant)	5397.112	2030.130		2.659	.010
	Frequency 7:00h - 9:00h	2222.148	237.039	.716	9.375	<.001
	Speed	-163.181	53.421	-.233	-3.055	.003
3	(Constant)	2027.700	2291.300		.885	.379
	Frequency 7:00h - 9:00h	1807.096	271.757	.582	6.650	<.001
	Speed	-159.559	51.120	-.228	-3.121	.003
	Shelter	64.443	23.256	.243	2.771	.007
4	(Constant)	-6745.404	3000.907		-2.248	.028
	Frequency 7:00h - 9:00h	2001.277	250.964	.645	7.974	<.001
	Speed	-108.362	48.032	-.155	-2.256	.027
	Shelter	99.368	22.776	.374	4.363	<.001
	Stops	68.571	16.929	.326	4.050	<.001
5	(Constant)	-5540.591	2912.314		-1.902	.061
	Frequency 7:00h - 9:00h	2241.239	256.817	.722	8.727	<.001
	Speed	-132.147	46.904	-.189	-2.817	.006
	Shelter	98.535	21.840	.371	4.512	<.001
	Stops	64.272	16.311	.306	3.940	<.001
	Cancelled kilometres	-430.382	160.987	-.193	-2.673	.009

a. Dependent Variable: #passengers

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	Speed	-.233[b]	-3.055	.003	-.339	.999
	Punctuality	-.107[b]	-1.334	.186	-.155	.997
	Cancelled kilometres	-.165[b]	-1.863	.067	-.214	.805
	Bicycle Parking	.000[b]	.002	.998	.000	.640
	Shelter	.250[b]	2.693	.009	.303	.695
	DRIS	.297[b]	2.911	.005	.325	.566
	BHLS service	-.039[b]	-.395	.694	-.047	.665
	BHLS vehicle deployment	.092[b]	.755	.453	.089	.438
	Stops	.243[b]	2.887	.005	.322	.835
	Frequency 19:00h - 21:00h	.232[b]	1.707	.092	.197	.343
2	Punctuality	-.056[c]	-.708	.481	-.084	.943
	Cancelled kilometres	-.215[c]	-2.588	.012	-.294	.782
	Bicycle Parking	.138[c]	1.331	.188	.156	.539
	Shelter	.243[c]	2.771	.007	.312	.695
	DRIS	.191[c]	1.661	.101	.193	.430
	BHLS service	.171[c]	1.540	.128	.180	.462
	BHLS vehicle deployment	.142[c]	1.224	.225	.144	.430
	Stops	.193[c]	2.314	.024	.265	.789
	Frequency 19:00h - 21:00h	.098[c]	.695	.489	.082	.296
3	Punctuality	-.083[d]	-1.094	.278	-.130	.929
	Cancelled kilometres	-.221[d]	-2.800	.007	-.317	.781
	Bicycle Parking	.019[d]	.166	.869	.020	.432
	DRIS	.083[d]	.685	.496	.082	.364
	BHLS service	.090[d]	.797	.428	.095	.420
	BHLS vehicle deployment	.128[d]	1.152	.253	.136	.429
	Stops	.326[d]	4.050	<.001	.436	.676
	Frequency 19:00h - 21:00h	.133[d]	.987	.327	.117	.294
4	Punctuality	-.037[e]	-.522	.603	-.063	.902
	Cancelled kilometres	-.193[e]	-2.673	.009	-.306	.773
	Bicycle Parking	-.004[e]	-.039	.969	-.005	.431
	DRIS	.166[e]	1.500	.138	.178	.353
	BHLS service	.079[e]	.770	.444	.092	.420
	BHLS vehicle deployment	.072[e]	.702	.485	.084	.420
	Frequency 19:00h - 21:00h	.159[e]	1.309	.195	.156	.293
5	Punctuality	-.051[f]	-.751	.455	-.091	.897
	Bicycle Parking	-.004[f]	-.041	.967	-.005	.431
	DRIS	.170[f]	1.606	.113	.191	.353
	BHLS service	-.003[f]	-.027	.979	-.003	.379
	BHLS vehicle deployment	.017[f]	.170	.866	.021	.401
	Frequency 19:00h - 21:00h	.211[f]	1.811	.075	.214	.286

a. Dependent Variable: #passengers

b. Predictors in the Model: (Constant), Frequency 7:00h - 9:00h

c. Predictors in the Model: (Constant), Frequency 7:00h - 9:00h, Speed

d. Predictors in the Model: (Constant), Frequency 7:00h - 9:00h, Speed, Shelter

e. Predictors in the Model: (Constant), Frequency 7:00h - 9:00h, Speed, Shelter, Stops

f. Predictors in the Model: (Constant), Frequency 7:00h - 9:00h, Speed, Shelter, Stops, Cancelled kilometres

Model with regional coefficients

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.707[a]	.499	.492	3814.535
2	.763[b]	.582	.570	3510.356
3	.789[c]	.623	.607	3357.231
4	.821[d]	.674	.655	3142.368
5	.846[e]	.716	.696	2953.934
6	.864[f]	.746	.723	2816.416

a. Predictors: (Constant), Frequency 7:00h – 9:00h Randstad

b. Predictors: (Constant), Frequency 7:00h – 9:00h Randstad, Speed ZaWa

c. Predictors: (Constant), Frequency 7:00h – 9:00h Randstad, Speed ZaWa, Frequency 7:00h – 9:00h IJV

d. Predictors: (Constant), Frequency 7:00h – 9:00h Randstad, Speed ZaWa, Frequency 7:00h – 9:00h IJV, Stops

e. Predictors: (Constant), Frequency 7:00h – 9:00h Randstad, Speed ZaWa, Frequency 7:00h – 9:00h IJV, Stops, Shelter Randstad

f. Predictors: (Constant), Frequency 7:00h – 9:00h Randstad, Speed ZaWa, Frequency 7:00h – 9:00h IJV, Stops, Shelter Randstad, Shelter IJV

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1058740095	1	1058740095	72.762	<.001[b]
	Residual	1062199258	73	14550674.8		
	Total	2120939353	74			
2	Regression	1233711983	2	616855991	50.059	<.001[c]
	Residual	887227371	72	12322602.4		
	Total	2120939353	74			
3	Regression	1320698385	3	440232795	39.059	<.001[d]
	Residual	800240968	71	11270999.6		
	Total	2120939353	74			
4	Regression	1429725943	4	357431486	36.198	<.001[e]
	Residual	691213410	70	9874477.285		
	Total	2120939353	74			
5	Regression	1518864407	5	303772881	34.813	<.001[f]
	Residual	602074946	69	8725723.857		
	Total	2120939353	74			
6	Regression	1581549905	6	263591651	33.231	<.001[g]
	Residual	539389449	68	7932197.774		
	Total	2120939353	74			

a. Dependent Variable: #passengers

b. Predictors: (Constant), Frequency 7:00h – 9:00h Randstad

c. Predictors: (Constant), Frequency 7:00h – 9:00h Randstad, Speed ZaWa

d. Predictors: (Constant), Frequency 7:00h – 9:00h Randstad, Speed ZaWa, Frequency 7:00h – 9:00h IJV

e. Predictors: (Constant), Frequency 7:00h – 9:00h Randstad, Speed ZaWa, Frequency 7:00h – 9:00h IJV, Stops

f. Predictors: (Constant), Frequency 7:00h – 9:00h Randstad, Speed ZaWa, Frequency 7:00h – 9:00h IJV, Stops, Shelter Randstad

g. Predictors: (Constant), Frequency 7:00h – 9:00h Randstad, Speed ZaWa, Frequency 7:00h – 9:00h IJV, Stops, Shelter Randstad, Shelter IJV

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3107.085	593.890		5.232	<.001
	Frequency 7:00h - 9:00h Randstad	1605.402	188.205	.707	8.530	<.001
2	(Constant)	3141.465	546.608		5.747	<.001
	Frequency 7:00h - 9:00h Randstad	2232.612	240.213	.983	9.294	<.001
	Speed ZaWa	-133.746	35.493	-.398	-3.768	<.001
3	(Constant)	872.043	969.853		.899	.372
	Frequency 7:00h - 9:00h Randstad	2703.354	285.466	1.190	9.470	<.001
	Speed ZaWa	-131.286	33.957	-.391	-3.866	<.001
	Frequency 7:00h - 9:00h IJV	1391.789	500.990	.293	2.778	.007
4	(Constant)	-3028.223	1483.848		-2.041	.045
	Frequency 7:00h - 9:00h Randstad	3000.897	281.801	1.321	10.649	<.001
	Speed ZaWa	-130.624	31.784	-.389	-4.110	<.001
	Frequency 7:00h - 9:00h IJV	1636.775	474.687	.345	3.448	<.001
	Stops	52.208	15.712	.248	3.323	.001
5	(Constant)	-5294.395	1564.728		-3.384	.001
	Frequency 7:00h - 9:00h Randstad	2209.259	362.657	.972	6.092	<.001
	Speed ZaWa	-120.429	30.048	-.359	-4.008	<.001
	Frequency 7:00h - 9:00h IJV	2621.622	542.272	.553	4.835	<.001
	Stops	52.249	14.770	.249	3.538	<.001
	Shelter Randstad	70.049	21.916	.539	3.196	.002
6	(Constant)	-9372.523	2080.916		-4.504	<.001
	Frequency 7:00h - 9:00h Randstad	2258.156	346.211	.994	6.522	<.001
	Speed ZaWa	-113.442	28.757	-.338	-3.945	<.001
	Frequency 7:00h - 9:00h IJV	1998.057	562.601	.421	3.551	<.001
	Stops	70.354	15.485	.335	4.543	<.001
	Shelter Randstad	104.462	24.218	.804	4.313	<.001
	Shelter IJV	70.837	25.198	.432	2.811	.006

a. Dependent Variable: #passengers

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	Speed ZaWa	-.398[b]	-3.768	<.001	-.406	.520
	Speed MRDH	.197[b]	2.328	.023	.265	.907
	Speed IJV	.057[b]	.383	.703	.045	.315
	Punctuality	-.053[b]	-.643	.522	-.076	1.000
	Cancelled kms ZaWa	-.329[b]	-3.669	<.001	-.397	.728
	Cancelled kms MRDH	.105[b]	1.220	.226	.142	.922
	Frequency 7:00h - 9:00h IJV	.304[b]	2.636	.010	.297	.477
	Bicycle parking Randstad	-.010[b]	-.055	.956	-.006	.200
	Bicycle parking IJV	.205[b]	1.612	.111	.187	.414
	Shelter Randstad	.156[b]	.874	.385	.102	.216
	Shelter IJV	.163[b]	1.258	.213	.147	.407
	DRIS Randstad	.204[b]	1.349	.181	.157	.296
	DRIS IJV	.138[b]	1.429	.157	.166	.731
	BHLS service	.163[b]	1.868	.066	.215	.873
	BHLS vehicle deployment	.261[b]	2.662	.010	.299	.660
	Stops	.209[b]	2.407	.019	.273	.854
2	Speed MRDH	-.127[c]	-.949	.346	-.112	.323
	Speed IJV	.038[c]	.278	.782	.033	.314
	Punctuality	-.130[c]	-1.671	.099	-.195	.942
	Cancelled kms ZaWa	-.189[c]	-1.602	.114	-.187	.408
	Cancelled kms MRDH	-.157[c]	-1.513	.135	-.177	.530
	Frequency 7:00h - 9:00h IJV	.293[c]	2.778	.007	.313	.476
	Bicycle parking Randstad	.066[c]	.381	.705	.045	.197
	Bicycle parking IJV	.192[c]	1.641	.105	.191	.413
	Shelter Randstad	.112[c]	.678	.500	.080	.215
	Shelter IJV	.149[c]	1.254	.214	.147	.407
	DRIS Randstad	.078[c]	.538	.592	.064	.278
	DRIS IJV	.132[c]	1.498	.138	.175	.731
	BHLS service	.167[c]	2.101	.039	.242	.873
	BHLS vehicle deployment	.221[c]	2.417	.018	.276	.650
	Stops	.208[c]	2.627	.011	.298	.854
3	Speed MRDH	.099[d]	.644	.522	.077	.225
	Speed IJV	-.252[d]	-1.604	.113	-.188	.211
	Punctuality	-.167[d]	-2.253	.027	-.260	.919
	Cancelled kms ZaWa	-.160[d]	-1.402	.165	-.165	.404
	Cancelled kms MRDH	-.091[d]	-.880	.382	-.105	.494
	Bicycle parking Randstad	.223[d]	1.301	.198	.154	.179
	Bicycle parking IJV	-.112[d]	-.637	.526	-.076	.175
	Shelter Randstad	.539[d]	2.959	.004	.333	.144
	Shelter IJV	-.084[d]	-.567	.572	-.068	.246
	DRIS Randstad	.314[d]	2.074	.042	.241	.222
	DRIS IJV	-.036[d]	-.323	.748	-.039	.424
	BHLS service	.054[d]	.539	.592	.064	.538
	BHLS vehicle deployment	.105[d]	.902	.370	.107	.394
	Stops	.248[d]	3.323	.001	.369	.833
4	Speed MRDH	.116[e]	.806	.423	.097	.225
	Speed IJV	-.162[e]	-1.074	.286	-.128	.203
	Punctuality	-.112[e]	-1.525	.132	-.181	.854
	Cancelled kms ZaWa	-.130[e]	-1.211	.230	-.144	.401
	Cancelled kms MRDH	-.089[e]	-.919	.361	-.110	.494
	Bicycle parking Randstad	.243[e]	1.518	.134	.180	.179
	Bicycle parking IJV	.040[e]	.235	.815	.028	.161
	Shelter Randstad	.539[e]	3.196	.002	.359	.144
	Shelter IJV	.097[e]	.653	.516	.078	.213
	DRIS Randstad	.347[e]	2.479	.016	.286	.221
	DRIS IJV	.021[e]	.193	.848	.023	.412
	BHLS service	.140[e]	1.467	.147	.174	.504
	BHLS vehicle deployment	.082[e]	.747	.458	.090	.393

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5	Speed MRDH	-.228[f]	-1.349	.182	-.161	.143
	Speed IJV	.355[f]	1.740	.086	.206	.096
	Punctuality	-.086[f]	-1.229	.223	-.147	.841
	Cancelled kms ZaWa	-.151[f]	-1.499	.139	-.179	.399
	Cancelled kms MRDH	-.152[f]	-1.653	.103	-.197	.475
	Bicycle parking Randstad	.001[f]	.008	.994	.001	.134
	Bicycle parking IJV	.310[f]	1.789	.078	.212	.133
	Shelter IJV	.432[f]	2.811	.006	.323	.158
	DRIS Randstad	.086[f]	.453	.652	.055	.115
	DRIS IJV	.000[f]	.002	.998	.000	.411
	BHLS service	.137[f]	1.536	.129	.183	.504
	BHLS vehicle deployment	.050[f]	.484	.630	.059	.389
6	Speed MRDH	-.112[g]	-.666	.508	-.081	.132
	Speed IJV	.106[g]	.463	.645	.056	.072
	Punctuality	-.108[g]	-1.626	.109	-.195	.831
	Cancelled kms ZaWa	-.129[g]	-1.331	.188	-.160	.396
	Cancelled kms MRDH	-.125[g]	-1.410	.163	-.170	.469
	Bicycle parking Randstad	-.005[g]	-.028	.977	-.003	.134
	Bicycle parking IJV	.012[g]	.056	.955	.007	.078
	DRIS Randstad	.119[g]	.654	.515	.080	.114
	DRIS IJV	.028[g]	.295	.769	.036	.406
	BHLS service	.059[g]	.636	.527	.077	.441
	BHLS vehicle deployment	.028[g]	.283	.778	.035	.386

a. Dependent Variable: #passengers

b. Predictors in the Model: (Constant), Frequency 7:00h - 9:00h Randstad

c. Predictors in the Model: (Constant), Frequency 7:00h - 9:00h Randstad, Speed ZaWa

d. Predictors in the Model: (Constant), Frequency 7:00h - 9:00h Randstad, Speed ZaWa, Frequency 7:00h - 9:00h IJV

e. Predictors in the Model: (Constant), Frequency 7:00h - 9:00h Randstad, Speed ZaWa, Frequency 7:00h - 9:00h IJV, Stops

f. Predictors in the Model: (Constant), Frequency 7:00h - 9:00h Randstad, Speed ZaWa, Frequency 7:00h - 9:00h IJV, Stops, Shelter Randstad

g. Predictors in the Model: (Constant), Frequency 7:00h - 9:00h Randstad, Speed ZaWa, Frequency 7:00h - 9:00h IJV, Stops, Shelter Randstad, Shelter IJV

Appendix D Regression 12:00h – 14:00h

This appendix relates to the development of the off-peak regression model as described in Chapter 6. The contents in this appendix are:

- Correlation matrix
- Statistical tests to determine the regression coefficients
- IBM SPSS Statistics output tables of the base model
- IBM SPSS Statistics output tables of the model with regional coefficients
- Validation results

Testing for high correlation

Table D.1 Correlation matrix BHLS aspects (12:00h - 14:00h)

	Speed	*Punctuality*	*Cancelled kilometres*	*Frequency 7h - 9h*	*Frequency 12h - 14h*	*Frequency 19h - 21h*	*Bicycle Parking*	*Shelter*	*DRIS*	*BHLS service*	*BHLS vehicles*	*Stops*
Speed	1	.257	-.222	.013	-.213	-.188	.335	.006	.354	.467	.115	-.198
Punctuality	.257	1	-.082	.112	-.018	-.027	.285	.284	.092	.149	.018	-.238
Cancelled kilometres	-.222	-.082	1	-.043	.095	.013	-.104	-.062	.030	-.104	-.056	-.013
Frequency 7h - 9h	.013	.112	-.043	1	.848	.807	.597	.553	.654	.604	.751	-.435
Frequency 12h - 14h	-.213	-.018	.095	.848	1	.824	.455	.542	.710	.507	.702	-.337
Frequency 19h - 21h	-.188	-.027	.013	.807	.824	1	.419	.408	.579	.385	.594	-.337
Bicycle Parking	.335	.285	-.104	.597	.455	.419	1	.596	.330	.521	.434	-.405
Shelter	.006	.284	-.062	.553	.542	.408	.596	1	.590	.476	.432	-.511
DRIS	.354	.092	.030	.654	.710	.579	.330	.590	1	.301	.428	-.378
BHLS service	.467	.149	-.104	.604	.507	.385	.521	.476	.301	1	.783	-.393
BHLS vehicles	.115	.018	-.056	.751	.702	.594	.434	.432	.428	.783	1	-.270
Stops	-.198	-.238	-.013	-.435	-.337	-.337	-.405	-.511	-.378	-.393	-.270	1

Exploring the need for regional regression coefficients

Table D.2 ANOVA test results (12:00h - 14:00h)

Aspect	F test result	p-value
Operational speed	12.67	0.000
Punctuality	0.30	0.742
Cancelled kilometres	3.00	0.056
Frequency 7:00h – 9:00h	22.10	0.000
Frequency 12:00h – 14:00h	32.48	0.000
Frequency 19:00h – 21:00h	29.22	0.000
Bicycle parking	2.89	0.062
Shelter	11.13	0.000
DRIS	55.57	0.000
Number of stops	3.27	0.044

Table D.3 t-test results BHLS aspects ZaWa – MRDH (12:00h – 14:00h)

Aspect	t-test result (absolute value)	p-value
Operational speed	2.18	0.036
Frequency 7:00h – 9:00h	2.01	0.052
Frequency 12:00h – 14:00h	0.82	0.415
Frequency 19:00h – 21:00h	2.50	0.017
Shelter	0.24	0.812
DRIS	1.52	0.137
Number of stops	0.63	0.530

Table D.4 Regression coefficients to be estimated (12:00h - 14:00h)

Aspect	Base model	Model with regional coefficients
Speed	β_{speed}	$\beta_{speed,ZaWa}$; $\beta_{speed,MRDH}$; $\beta_{speed,IJV}$
Punctuality	$\beta_{punctuality}$	$\beta_{punctuality}$
Cancelled kilometres	$\beta_{cancelled}$	$\beta_{cancelled}$
Frequency 7:00h – 9:00h	$\beta_{freq\ 7-9}$	$\beta_{freq\ 7-9,Randstad}$; $\beta_{freq\ 7-9,IJV}$
Frequency 12:00h – 14:00h	$\beta_{freq\ 12-14}$	$\beta_{freq\ 12-14,Randstad}$; $\beta_{freq\ 12-14,IJV}$
Frequency 19:00h – 21:00h	$\beta_{freq\ 19-21}$	$\beta_{freq\ 19-21,ZaWa}$; $\beta_{freq\ 19-21,MRDH}$; $\beta_{freq\ 19-21,IJV}$
Bicycle Parking	$\beta_{bicycle}$	$\beta_{bicycle}$
Shelter	$\beta_{shelter}$	$\beta_{shelter,Randstad}$; $\beta_{shelter,IJV}$
DRIS	β_{DRIS}	$\beta_{DRIS,Randstad}$; $\beta_{DRIS,IJV}$
BHLS service	$\beta_{BHLS\ service}$	$\beta_{BHLS\ service}$
BHLS vehicles deployed on BHLS lines	$\beta_{BHLS\ vehicle}$	$\beta_{BHLS\ vehicle}$
Number of stops	β_{stops}	$\beta_{stops,Randstad}$; $\beta_{stops,IJV}$

Output tables base model

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.767[a]	.588	.582	2249.949
2	.821[b]	.674	.664	2016.022
3	.860[c]	.739	.728	1814.909

a. Predictors: (Constant), Frequency 12:00h - 14:00h

b. Predictors: (Constant), Frequency 12:00h - 14:00h, Stops

c. Predictors: (Constant), Frequency 12:00h - 14:00h, Stops, Shelter

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	504975791	1	504975791	99.753	<.001[b]
	Residual	354358984	70	5062271.201		
	Total	859334775	71			
2	Regression	578894885	2	289447442	71.216	<.001[c]
	Residual	280439890	69	4064346.232		
	Total	859334775	71			
3	Regression	635349823	3	211783274	64.296	<.001[d]
	Residual	223984952	68	3293896.350		
	Total	859334775	71			

a. Dependent Variable: #passengers

b. Predictors: (Constant), Frequency 12:00h - 14:00h

c. Predictors: (Constant), Frequency 12:00h - 14:00h, Stops

d. Predictors: (Constant), Frequency 12:00h - 14:00h, Stops, Shelter

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-994.790	589.974		-1.686	.096
	Frequency 12:00h - 14:00h	2314.454	231.732	.767	9.988	<.001
2	(Constant)	-4407.718	959.119		-4.596	<.001
	Frequency 12:00h - 14:00h	2697.567	226.239	.893	11.924	<.001
	Stops	43.159	10.120	.320	4.265	<.001
3	(Constant)	-8359.281	1287.084		-6.495	<.001
	Frequency 12:00h - 14:00h	2296.071	225.581	.760	10.178	<.001
	Stops	58.792	9.862	.435	5.961	<.001
	Shelter	56.276	13.593	.330	4.140	<.001

a. Dependent Variable: #passengers

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	Speed	-.171[b]	-2.233	.029	-.260	.955
	Punctuality	-.062[b]	-.802	.426	-.096	1.000
	Cancelled kilometres	-.136[b]	-1.788	.078	-.210	.991
	Frequency 7:00h - 9:00h	-.092[b]	-.627	.533	-.075	.278
	Frequency 19:00h - 21:00h	-.001[b]	-.007	.994	-.001	.321
	Bicycle parking	-.025[b]	-.285	.776	-.034	.793
	Shelter	.148[b]	1.641	.105	.194	.706
	DRIS	.176[b]	1.633	.107	.193	.496
	BHLS service	-.072[b]	-.804	.424	-.096	.743
	BHLS vehicle deployment	-.037[b]	-.345	.731	-.041	.507
	Stops	.320[b]	4.265	<.001	.457	.842
2	Speed	-.084[c]	-1.141	.258	-.137	.860
	Punctuality	.018[c]	.251	.802	.030	.928
	Cancelled kilometres	-.144[c]	-2.132	.037	-.250	.990
	Frequency 7:00h - 9:00h	.021[c]	.158	.875	.019	.267
	Frequency 19:00h - 21:00h	.009[c]	.072	.943	.009	.321
	Bicycle parking	.071[c]	.881	.381	.106	.734
	Shelter	.330[c]	4.140	<.001	.449	.603
	DRIS	.244[c]	2.564	.013	.297	.485
	BHLS service	.011[c]	.134	.894	.016	.699
	BHLS vehicle deployment	-.043[c]	-.440	.661	-.053	.507
3	Speed	-.093[d]	-1.406	.164	-.169	.859
	Punctuality	-.060[d]	-.902	.370	-.110	.857
	Cancelled kilometres	-.111[d]	-1.789	.078	-.214	.972
	Frequency 7:00h - 9:00h	-.052[d]	-.425	.672	-.052	.262
	Frequency 19:00h - 21:00h	.052[d]	.472	.638	.058	.318
	Bicycle parking	-.062[d]	-.775	.441	-.094	.612
	DRIS	.141[d]	1.518	.134	.182	.436
	BHLS service	-.055[d]	-.718	.475	-.087	.670
	BHLS vehicle deployment	-.079[d]	-.899	.372	-.109	.502

a. Dependent Variable: #passengers

b. Predictors in the Model: (Constant), Frequency 12:00h - 14:00h

c. Predictors in the Model: (Constant), Frequency 12:00h - 14:00h, Stops

d. Predictors in the Model: (Constant), Frequency 12:00h - 14:00h, Stops, Shelter

Output tables model with regional coefficients

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.696[a]	.485	.477	2515.356
2	.767[b]	.588	.576	2265.007
3	.835[c]	.697	.684	1956.772
4	.866[d]	.750	.735	1791.341
5	.889[e]	.791	.775	1651.153
6	.901[f]	.812	.795	1575.756
7	.907[g]	.823	.804	1539.685
8	.917[h]	.840	.820	1475.820

a. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad

b. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV

c. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV, Stops Randstad

d. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV, Stops Randstad, Speed ZaWa

e. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV, Stops Randstad, Speed ZaWa, Cancelled kilometres

f. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV, Stops Randstad, Speed ZaWa, Cancelled kilometres, Speed IJV

g. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV, Stops Randstad, Speed ZaWa, Cancelled kilometres, Speed IJV, Shelter Randstad

h. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV, Stops Randstad, Speed ZaWa, Cancelled kilometres, Speed IJV, Shelter Randstad, Stops IJV

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	416443617	1	416443617	65.820	<.001[b]
	Residual	442891158	70	6327016.542		
	Total	859334775	71			
2	Regression	505347087	2	252673543	49.252	<.001[c]
	Residual	353987688	69	5130256.355		
	Total	859334775	71			
3	Regression	598965649	3	199655216	52.143	<.001[d]
	Residual	260369126	68	3828957.738		
	Total	859334775	71			
4	Regression	644338278	4	161084570	50.199	<.001[e]
	Residual	214996497	67	3208902.936		
	Total	859334775	71			
5	Regression	679398579	5	135879716	49.840	<.001[f]
	Residual	179936196	66	2726306.005		
	Total	859334775	71			
6	Regression	697939331	6	116323222	46.848	<.001[g]
	Residual	161395444	65	2483006.825		
	Total	859334775	71			
7	Regression	707614521	7	101087789	42.642	<.001[h]
	Residual	151720254	64	2370628.968		
	Total	859334775	71			
8	Regression	722117984	8	90264748.0	41.443	<.001[i]
	Residual	137216791	63	2178044.296		
	Total	859334775	71			

a. Dependent Variable: #passengers

b. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad

c. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV

d. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV, Stops Randstad

e. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV, Stops Randstad, Speed ZaWa

f. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV, Stops Randstad, Speed ZaWa, Cancelled kilometres

g. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV, Stops Randstad, Speed ZaWa, Cancelled kilometres, Speed IJV

h. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV, Stops Randstad, Speed ZaWa, Cancelled kilometres, Speed IJV, Shelter Randstad

i. Predictors: (Constant), Frequency 12:00h – 14:00h Randstad, Frequency 12:00h – 14:00h IJV, Stops Randstad, Speed ZaWa, Cancelled kilometres, Speed IJV, Shelter Randstad, Stops IJV

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1877.867	418.019		4.492	<.001
	Frequency 12:00h - 14:00h Randstad	1443.694	177.949	.696	8.113	<.001
2	(Constant)	-1146.175	818.168		-1.401	.166
	Frequency 12:00h - 14:00h Randstad	2351.335	270.583	1.134	8.690	<.001
	Frequency 12:00h - 14:00h IJV	2460.559	591.077	.543	4.163	<.001
3	(Constant)	-3677.013	872.681		-4.213	<.001
	Frequency 12:00h - 14:00h Randstad	2256.005	234.554	1.088	9.618	<.001
	Frequency 12:00h - 14:00h IJV	4083.944	607.074	.901	6.727	<.001
	Stops Randstad	57.978	11.725	.516	4.945	<.001
4	(Constant)	-3229.104	807.733		-3.998	<.001
	Frequency 12:00h - 14:00h Randstad	2527.332	226.524	1.219	11.157	<.001
	Frequency 12:00h - 14:00h IJV	3796.636	560.978	.838	6.768	<.001
	Stops Randstad	55.708	10.751	.496	5.182	<.001
	Speed ZaWa	-61.781	16.430	-.287	-3.760	<.001
5	(Constant)	-2914.796	749.662		-3.888	<.001
	Frequency 12:00h - 14:00h Randstad	2478.660	209.237	1.195	11.846	<.001
	Frequency 12:00h - 14:00h IJV	3728.096	517.430	.823	7.205	<.001
	Stops Randstad	63.521	10.146	.565	6.261	<.001
	Speed ZaWa	-60.050	15.152	-.279	-3.963	<.001
	Cancelled kilometres	-490.528	136.786	-.214	-3.586	<.001
6	(Constant)	-5143.350	1084.876		-4.741	<.001
	Frequency 12:00h - 14:00h Randstad	2850.387	241.617	1.374	11.797	<.001
	Frequency 12:00h - 14:00h IJV	3139.647	538.715	.693	5.828	<.001
	Stops Randstad	81.159	11.637	.722	6.974	<.001
	Speed ZaWa	-53.310	14.669	-.248	-3.634	<.001
	Cancelled kilometres	-500.659	130.593	-.218	-3.834	<.001
	Speed IJV	82.669	30.253	.464	2.733	.008
7	(Constant)	-6806.795	1342.265		-5.071	<.001
	Frequency 12:00h - 14:00h Randstad	2559.034	276.651	1.234	9.250	<.001
	Frequency 12:00h - 14:00h IJV	3359.107	537.476	.741	6.250	<.001
	Stops Randstad	78.670	11.437	.700	6.879	<.001
	Speed ZaWa	-54.305	14.342	-.252	-3.787	<.001
	Cancelled kilometres	-428.224	132.545	-.187	-3.231	.002
	Speed IJV	116.540	33.984	.654	3.429	.001
	Shelter Randstad	33.128	16.398	.392	2.020	.048
8	(Constant)	-8440.242	1433.875		-5.886	<.001
	Frequency 12:00h - 14:00h Randstad	2614.148	266.034	1.261	9.826	<.001
	Frequency 12:00h - 14:00h IJV	3298.167	515.722	.728	6.395	<.001
	Stops Randstad	84.947	11.229	.756	7.565	<.001
	Speed ZaWa	-51.841	13.780	-.241	-3.762	<.001
	Cancelled kilometres	-372.823	128.849	-.163	-2.893	.005
	Speed IJV	120.407	32.609	.676	3.692	<.001
	Shelter Randstad	45.772	16.464	.541	2.780	.007
	Stops IJV	23.517	9.113	.259	2.580	.012

a. Dependent Variable: #passengers

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	Speed ZaWa	-.354[b]	-3.616	<.001	-.399	.654
	Speed MRDH	.127[b]	1.369	.176	.163	.845
	Speed IJV	.356[b]	2.102	.039	.245	.244
	Punctuality	-.105[b]	-1.229	.223	-.146	.998
	Cancelled kilometres	-.194[b]	-2.285	.025	-.265	.967
	Frequency 7:00h - 9:00h Randstad	-.282[b]	-1.158	.251	-.138	.124
	Frequency 7:00h - 9:00h IJV	.484[b]	4.041	<.001	.437	.420
	Frequency 12:00h - 14:00h IJV	.543[b]	4.163	<.001	.448	.351
	Bicycle parking	.084[b]	.906	.368	.108	.864
	Shelter Randstad	-.116[b]	-.562	.576	-.067	.174
	Shelter IJV	.323[b]	2.289	.025	.266	.348
	DRIS Randstad	.056[b]	.326	.746	.039	.253
	DRIS IJV	.248[b]	2.541	.013	.293	.718
	BHLS service	.128[b]	1.421	.160	.169	.900
	BHLS vehicle deployment	.195[b]	1.931	.058	.226	.696
	Stops Randstad	.136[b]	1.212	.229	.144	.579
	Stops IJV	.231[b]	1.705	.093	.201	.391
2	Speed ZaWa	-.309[c]	-3.454	<.001	-.386	.643
	Speed MRDH	.216[c]	2.607	.011	.301	.803
	Speed IJV	-.086[c]	-.426	.671	-.052	.148
	Punctuality	-.060[c]	-.764	.447	-.092	.977
	Cancelled kilometres	-.139[c]	-1.760	.083	-.209	.935
	Frequency 7:00h - 9:00h Randstad	-.252[c]	-1.148	.255	-.138	.124
	Frequency 7:00h - 9:00h IJV	.224[c]	.971	.335	.117	.113
	Bicycle parking	-.029[c]	-.324	.747	-.039	.778
	Shelter Randstad	.461[c]	2.110	.039	.248	.119
	Shelter IJV	-.010[c]	-.060	.952	-.007	.221
	DRIS Randstad	.350[c]	2.162	.034	.254	.217
	DRIS IJV	.027[c]	.232	.817	.028	.452
	BHLS service	-.102[c]	-1.023	.310	-.123	.600
	BHLS vehicle deployment	-.053[c]	-.459	.648	-.056	.450
	Stops Randstad	.516[c]	4.945	<.001	.514	.410
	Stops IJV	.030[c]	.221	.826	.027	.329
3	Speed ZaWa	-.287[d]	-3.760	<.001	-.417	.641
	Speed MRDH	.154[d]	2.088	.041	.247	.777
	Speed IJV	.553[d]	2.789	.007	.323	.103
	Punctuality	.047[d]	.664	.509	.081	.885
	Cancelled kilometres	-.221[d]	-3.363	.001	-.380	.893
	Frequency 7:00h - 9:00h Randstad	-.064[d]	-.328	.744	-.040	.119
	Frequency 7:00h - 9:00h IJV	.233[d]	1.176	.244	.142	.113
	Bicycle parking	.025[d]	.328	.744	.040	.762
	Shelter Randstad	.142[d]	.684	.496	.083	.104
	Shelter IJV	.242[d]	1.635	.107	.196	.198
	DRIS Randstad	.257[d]	1.807	.075	.216	.212
	DRIS IJV	-.033[d]	-.324	.747	-.040	.446
	BHLS service	-.010[d]	-.114	.909	-.014	.572
	BHLS vehicle deployment	.036[d]	.357	.722	.044	.436
	Stops IJV	.275[d]	2.268	.027	.267	.285

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4	Speed MRDH	-.251[e]	-1.924	.059	-.230	.211
	Speed IJV	.445[e]	2.389	.020	.282	.100
	Punctuality	.042[e]	.646	.521	.079	.884
	Cancelled kilometres	-.214[e]	-3.586	<.001	-.404	.892
	Frequency 7:00h - 9:00h Randstad	.342[e]	1.708	.092	.206	.090
	Frequency 7:00h - 9:00h IJV	.232[e]	1.278	.206	.155	.113
	Bicycle parking	.097[e]	1.349	.182	.164	.715
	Shelter Randstad	.217[e]	1.144	.257	.139	.103
	Shelter IJV	.199[e]	1.455	.150	.176	.196
	DRIS Randstad	.190[e]	1.428	.158	.173	.208
	DRIS IJV	-.022[e]	-.239	.812	-.029	.445
	BHLS service	.060[e]	.724	.472	.089	.544
	BHLS vehicle deployment	.075[e]	.803	.425	.098	.431
	Stops IJV	.235[e]	2.094	.040	.250	.283
5	Speed MRDH	-.301[f]	-2.542	.013	-.301	.208
	Speed IJV	.464[f]	2.733	.008	.321	.100
	Punctuality	.030[f]	.493	.624	.061	.881
	Frequency 7:00h - 9:00h Randstad	.172[f]	.883	.381	.109	.084
	Frequency 7:00h - 9:00h IJV	.228[f]	1.367	.176	.167	.113
	Bicycle parking	.069[f]	1.023	.310	.126	.704
	Shelter Randstad	.064[f]	.350	.728	.043	.097
	Shelter IJV	.205[f]	1.631	.108	.198	.196
	DRIS Randstad	.099[f]	.781	.438	.096	.198
	DRIS IJV	-.044[f]	-.519	.606	-.064	.443
	BHLS service	.047[f]	.614	.541	.076	.542
	BHLS vehicle deployment	.054[f]	.621	.537	.077	.428
	Stops IJV	.206[f]	1.979	.052	.238	.281
6	Speed MRDH	-.186[g]	-1.372	.175	-.169	.155
	Punctuality	.011[g]	.198	.844	.025	.869
	Frequency 7:00h - 9:00h Randstad	.225[g]	1.210	.231	.150	.083
	Frequency 7:00h - 9:00h IJV	.233[g]	1.471	.146	.181	.113
	Bicycle parking	.046[g]	.711	.480	.089	.691
	Shelter Randstad	.392[g]	2.020	.048	.245	.073
	Shelter IJV	.031[g]	.213	.832	.027	.137
	DRIS Randstad	.256[g]	2.016	.048	.244	.171
	DRIS IJV	-.040[g]	-.496	.622	-.062	.443
	BHLS service	-.026[g]	-.332	.741	-.041	.476
	BHLS vehicle deployment	.052[g]	.626	.534	.078	.428
	Stops IJV	.176[g]	1.747	.085	.213	.277
7	Speed MRDH	-.309[h]	-2.256	.028	-.273	.138
	Punctuality	-.012[h]	-.200	.842	-.025	.835
	Frequency 7:00h - 9:00h Randstad	.141[h]	.748	.457	.094	.078
	Frequency 7:00h - 9:00h IJV	.239[h]	1.543	.128	.191	.113
	Bicycle parking	-.010[h]	-.138	.891	-.017	.567
	Shelter IJV	.024[h]	.167	.868	.021	.136
	DRIS Randstad	.164[h]	1.074	.287	.134	.118
	DRIS IJV	-.052[h]	-.657	.513	-.083	.441
	BHLS service	-.085[h]	-1.054	.296	-.132	.426
	BHLS vehicle deployment	.024[h]	.290	.773	.036	.415
	Stops IJV	.259[h]	2.580	.012	.309	.252

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8	Speed MRDH	-.246[i]	-1.804	.076	-.223	.132
	Punctuality	.004[i]	.063	.950	.008	.826
	Frequency 7:00h - 9:00h Randstad	.142[i]	.782	.437	.099	.078
	Frequency 7:00h - 9:00h IJV	.278[i]	1.882	.065	.232	.112
	Bicycle parking	.018[i]	.264	.793	.033	.553
	Shelter IJV	.200[i]	1.349	.182	.169	.114
	DRIS Randstad	.186[i]	1.277	.206	.160	.118
	DRIS IJV	-.011[i]	-.136	.892	-.017	.420
	BHLS service	-.050[i]	-.635	.528	-.080	.411
	BHLS vehicle deployment	-.012[i]	-.148	.882	-.019	.402

a. Dependent Variable: #passengers

b. Predictors in the Model: (Constant), Frequency 12:00h - 14:00h Randstad

c. Predictors in the Model: (Constant), Frequency 12:00h - 14:00h Randstad, Frequency 12:00h - 14:00h IJV

d. Predictors in the Model: (Constant), Frequency 12:00h - 14:00h Randstad, Frequency 12:00h - 14:00h IJV, Stops Randstad

e. Predictors in the Model: (Constant), Frequency 12:00h - 14:00h Randstad, Frequency 12:00h - 14:00h IJV, Stops Randstad, Speed ZaWa

f. Predictors in the Model: (Constant), Frequency 12:00h - 14:00h Randstad, Frequency 12:00h - 14:00h IJV, Stops Randstad, Speed ZaWa, Cancelled kilometres

g. Predictors in the Model: (Constant), Frequency 12:00h - 14:00h Randstad, Frequency 12:00h - 14:00h IJV, Stops Randstad, Speed ZaWa, Cancelled kilometres, Speed IJV

h. Predictors in the Model: (Constant), Frequency 12:00h - 14:00h Randstad, Frequency 12:00h - 14:00h IJV, Stops Randstad, Speed ZaWa, Cancelled kilometres, Speed IJV, Shelter Randstad

i. Predictors in the Model: (Constant), Frequency 12:00h - 14:00h Randstad, Frequency 12:00h - 14:00h IJV, Stops Randstad, Speed ZaWa, Cancelled kilometres, Speed IJV, Shelter Randstad, Stops IJV

Model validation

Table D.5 Regression coefficients for different seeds (off-peak)

Regression coefficient	*Original*	*Seed 1*	*Seed 2*	*Seed 3*	*Seed 4*	*Seed 5*	*SD*
$\beta_{frequency\ 12-14,Randstad}$	1.261	1.282	1.325	1.291	1.227	1.309	.032
$\beta_{frequency\ 12-14,IJV}$	.728	.720	.715	.777	.576	.727	.062
$\beta_{stops,Randstad}$	.756	.817	.675	.785	.735	.754	.044
$\beta_{speed,ZaWa}$	-.241	-.227	-.153	-.255	-.278	-.212	.039
$\beta_{cancelled\ kilometres}$	-.163	-.210	-.152	-.147	-.167	-.164	.020
$\beta_{speed,IJV}$	.676	.558	.630	.694	.815	.823	.095
$\beta_{shelter,Randstad}$	.541	.348*	.476	.514	.609	.561	.082
$\beta_{stops,IJV}$	.259	.261	.295	.239	.249	.181*	.034

**p*-value > .05

Table D.6 RMSE for different seeds (12:00h – 14:00h)

	Seed 1	*Seed 2*	*Seed 3*	*Seed 4*	*Seed 5*
RMSE	1997.24	1921.40	1718.16	1815.16	1711.57