Assessing Integration of Bus Networks with Non-Motorised Access and Egress Modalities

Case Study:

Bus Network Integration with Access and Egress Modalities in Amstelland-Meerlanden

Master Thesis

MSc Transport, Infrastructure and Logistics
Delft University of Technology
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Stadsregio Amsterdam

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Judith Caroline Brand

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Master Thesis

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You have brains in your head. You have feet in your shoes. You can steer yourself any direction you choose. You're on your own. And you know what you know. And YOU are the one who'll decide where to go…

— Dr. Seuss. ***Oh. The Places You'll Go!***

Preface

Finally, it is done, and it feels good! While typing these final pages of my thesis, I can gratefully say that my years as a student are over. What a journey it was! Although these past years have not always been easy, they have helped me to achieve what am today: wiser, older, but most importantly, ready for a new start in a new country!

Just like I was ready six months ago, for the final chapter of my studies, my 'pièce de résistance', my master thesis. People who went before me already warned me: it would be difficult, it would cause screams, frustration and anger, but it would all be worth it in the end. And before I started, I would always think they were wrong, that I would be fine. And I was, to be honest, up until the last month before handing in my green-light report. The stress kicked in, the doubts flooded my mind, and my emigration plans did not help bringing down the worries. But having passed the 'point-of-no-return', by achieving 'green' during the green light meeting, I can now agree with the advice of my friends: it did cause screams, I was angry at times (mostly at myself, although a slow laptop does not help…), and I had sleepless nights just thinking about how to process my thoughts to paper. Well, here I am, grateful that it is over, acknowledging that it was difficult but worth it, and yes, I can actually say that I am proud of my achievements. So, when you read this thesis, please remember the amount of blood, sweat, tears and litres of tea that were needed to create my 'Magnum Opus'. So let me start of my 'Thanks' by thanking you, the reader of this thesis, for expressing interest in my research that took me a little over six months to complete.

So here it goes, my thanks to everyone who contributed to this thesis in one way or another. I would like to start with my thesis committee, Serge Hoogendoorn, Jan Anne Annema, Niels van Oort and Bart Schalkwijk. Serge, thank you for your advice and thank you so much for allowing me to take some extra time when other matters were more important. Jan Anne, thanks for the good and constructive advice about my writing. I found it difficult to translate my thoughts to paper, and our meetings have helped me to translate these in such a way you, and now others, will hopefully understand what I intended to say. Niels, thank you for introducing me to Stadsregio Amsterdam, without that initial meeting in December, I would not be where I am now. Thank you for the great input and advice you gave me before and during my research. And finally, I'd like to thank Bart. Our weekly meetings really contributed to this thesis. Thank you for helping me determine not only the scientific side of issues addressed in this research, but also the political and practical considerations that needed to be taken into account. I really appreciate you reading everything I send you, and you helping me during the course of this research.

I would like to thank everyone from Stadsregio Amsterdam who has proven to be helpful in the past couple of months. Thank you to everyone who was willing to answer my questions, both at random as well as in interviews. Many thanks as well to the external experts that have made time in their busy schedules to talk to me.

Thanks to my mom and dad, for giving me the brains and the determination to finish this project, for allowing me to take my time during my studies and for supporting me financially, but more importantly supporting me morally. Thank you to my sister Lianne, for the much needed days where I could relieve my stress. A great thanks to all my other family members and my friends, who did not always fully understood the struggles but supported me with their texts, cards, and whose small talk helped me focus on other things than writing.

I'd like to thank my future employer for offering me a job. It goes without saying that having something exiting to look forward to, helps tremendously, although procrastination was never an option as the result of the tight schedule (which I'm thankful for, really, and I am not at all jealous of my friends going on vacation during their research).

I would like to thank the developers of Excel for my daily portion of 10 minutes of panic and frustration. No fear of the blue screen of death, but the dreaded 'Excel ran out of resources while attempting to calculate one or more formulas' really gave me that extra shot of adrenaline that I so desperately needed.

I'd like to thank Bonnie, for facing the final month of our thesis battle together. Keeping each other on track, with great determination, sometimes a little less focus, and in the end nothing more to talk about other than our thesis (really, when you see each other every day, and your day consists of 8 hours of writing, your life gets really boring, which leaves nothing to talk about). Now that we are both graduating proves how well this worked.

A thank you to Maartje, for our evening walks, though not as frequent as we promised each other in the beginning (oh the dreaded weather in the Netherlands). Thank you for proof reading my thesis. Also a major thank you to Elisabeth, Dieke and Liselot, for proof reading this thesis, and correcting my English mistakes (although not all made unintentionally, as I think the difference between 'addition' and 'addiction' is small when your thesis is all you can think about, and has thus become an addiction in itself).

Right, I think with the end of this preface, we can all agree that writing in the quantitative sense of the word is not my biggest problem. The attentive reader might already have noticed the quote of Dr. Seuss. I can recommend everyone that is about to embark on the adventure of thesis writing and graduation, to read the book 'The places you'll go'. Although written for children, I think anyone that is about to start a new adventure, be it graduation, or, in my case now that I've finished my thesis, a move abroad, can relate to this masterpiece. With that, I'd like to finish this preface with some other wise words from the same book, as by finishing my life as a student, I'll start my life as a Dutchie in the UK.

You're off the Great Places!
Today is your day!
Your mountain is waiting.
So.... get on your way!

Judith Caroline Brand
Delft, the Netherlands, August 2015

Summary

Introduction

Demand for transportation is subject to change influenced by technological, spatial, societal and demographic aspects. The political environment, together with financial and spatial constraints limit the possibilities to address transport issues arising from growing demand through the construction of new infrastructure. Upgrading of existing services and improving integration over the entire trip chain are two options that can address these transport issues. However, there is a lack of (scientific) insights in the influence of service upgrades on the performance of the bus system, and a lack of (scientific) knowledge into the characteristics of the transport system that influence transport network integration. Hence, to be able to assess and improve integration in bus networks, insight is needed in:

- The differences in performance and effects between conventional and high quality bus services
- The causes and effects of network integration in Bus-NMT transport systems;
- The assessment of the performance of the entire transport chain as the result of transport network integration, considering the interaction of the transport network with its environment.

To be able to address these issues, a framework, with which transport network integration can be assessed, has to be developed, leading to the research question:

What are the main characteristics of the transport system and its environment that influence transport network integration, how do these characteristics relate to differences between conventional bus systems and high quality bus systems, and how can these characteristics be assessed using a framework?

Transport Network Integration

To be able to develop the assessment framework, insight is needed in the different concepts of integration and the elements and characteristics of the transport system. In this research, integration is described as *the combination of individual elements (links) of the transport chain, from a travellers' origin to its destination, thus combining different transport networks in one system, with the aim to positively influence effects of the transport system. This combination entails the integration of the different links through improvement of mode specific characteristics that influence integration, taking into account the environment of the entire system.*

The 'system' mentioned in the description of integration, needs to be explained in more detail. A system can be described as *'a collection of elements that is discernible within the total reality'*. The outcomes of the system, or 'emergence' is *'the principle that whole entities (groups of elements) display characteristics that are not only meaningful when they are assigned to the whole and can not be reduced to the individual elements'.* In this research, the integrated transport system consists of:

A. The Transport Chain
Which is the entire trip from origin (O) through the access node (AN) and egress node (EN), using the bus link, to the destination (D).

B. The Spatial and Demographic Elements
Which are the elements from the environment of the system, that influence the system, and as such are drivers of the system that determine the outcomes (effects).

C. The Effects of the Integrated Transport System
Which is the 'outcome' of the system, the effects of the system on travellers (e.g. total travel time) and society (e.g. emissions), which presents the way the integrated transport system influences the environment.

These different elements and their characteristics are the building blocks of the assessment framework.

Framework Development

Based on the literature research into transport network integration and the different elements of the integrated transport system, three different prerequisites have been identified that need to be captured in an assessment framework. These prerequisites (considerations) are:

- *The influence of network specific characteristics on transport network integration;*
  Implies that the framework should be able to identify and assess different characteristics of the system elements, and should be able to determine the influence of these characteristics on network integration.
- *The influence of the integrated transport system on (societal) effects;*
  Implies that the framework should be able to determine the effects of a system, and should be able to determine the influence of network integration on these effects.
- *The assessment and comparison of different systems in terms of characteristics and effects.*
  Implies that the framework should allow for the comparison and improvement of different bus systems.

To be able to address these considerations, the framework that has been developed consist of three individual parts that are influenced by one another, being:

- *Bus Line Performance Assessment;*
  Which involves the assessment of the different system elements and their characteristics of different (types of) bus services, including a comparison between different bus lines.
- *System Effect Assessment.*
  Which involves the assessment of the effects of the (optimised) integration of the individual systems, including a comparison between bus lines.
- *Integration Assessment,*
  Which involves the assessment of the manifestation of integration in transport networks and the related integration effects.

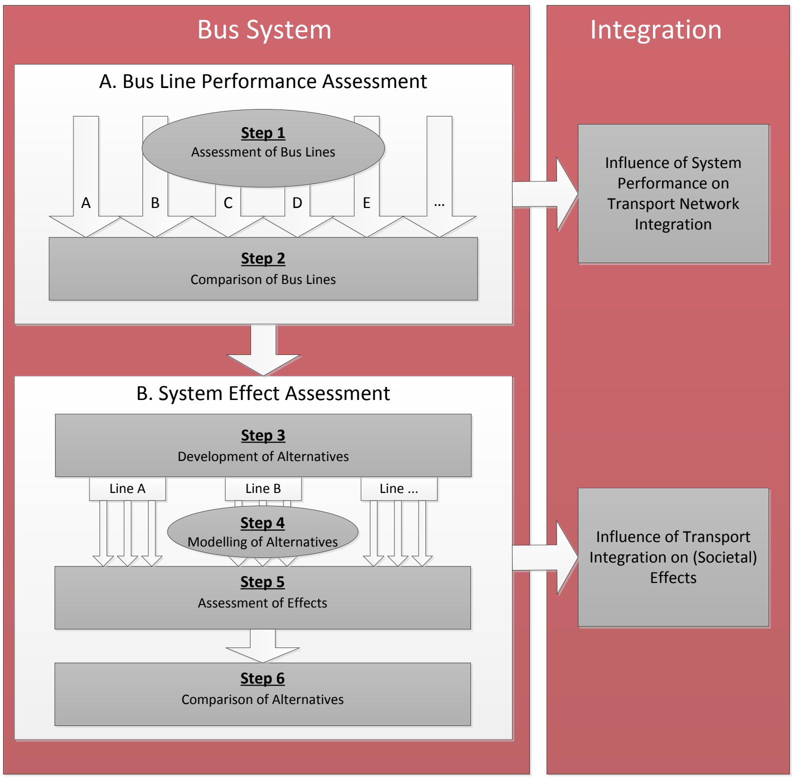

Figure 1: The Assessment Framework

The considerations, the building blocks (elements and their characteristics) and the three different parts of the assessment framework lead to the framework is presented in Figure 1Figure 34. This framework is tested using a case study.

Case Study: Assessment of Integration in Amstelland-Meerlanden

The case study has been carried out for the concession area Amstelland-Meerlanden of Stadsregio Amsterdam. Each step of the framework represents a different step in assessment.

Step 1: Assessment of Bus Lines

The first step involves the assessment of individual bus lines. The different bus lines are assessed on elements and characteristics, and are compared using a scorecard in step 2. General survey outcomes give a chance to give a general overview of system performance of the 10 assessed bus lines. The break-down of use of access and egress modalities for the bus lines is most important. This break down emphasises the need for more detailed knowledge in the use of access and egress modalities for bus networks. The bicycle is an important modality on the access side, whereas its share on the egress side is much smaller. This can be explained by the fact that on the access side of a trip, people often have more modalities at their disposal, and thus have a larger choice of modalities. On the egress side, these modalities are often not or less available. Furthermore, walking is more important on the egress side, suggesting distances on this side of the trip are often shorter, hence allowing for walking. These outcomes stress the importance of the bicycle on the access side, where for bus systems, walking and cycling are very often considered as one modality. Hence, the high use of the bus on both the access and egress side suggest that other bus services are important as feeder services to faster or last-mile bus services. Opportunities might exist on the egress side of the trip (last-mile) if these distances are short, for instance through the supply of cycle-hire facilities, thus aiming for competition between bus and bike for short last-mile distance.

Step 2: Comparison of Bus Lines

The bus system (lines) are compared in three different ways: by bus type, by bus line, and by stop.

The bus type comparison compares Comfortnet (conventional bus system) with R-Net (high quality bus-system). Striking is that for R-Net, the share of the bike, both for access and egress trips, is much higher than the share in Comfortnet lines (25% versus 11% access, and 10% versus 5% egress). One explanation could be that people accept longer trips for R-Net services due to the positive performance differences between R-Net and Comfortnet (e.g. higher speeds, higher frequencies). The accepted distances for access and egress for walking and cycling have been assessed in more detail. For R-Net, distances are often higher than for Comfortnet, with the exception of the bicycle use on the egress side.

The line based comparison allows for a more detailed comparison of the ten assessed bus lines. Characteristics per element are assessed. Using the equation for total travel time, the travel times per line can be determined for an in-vehicle distance of 10 km, hence allowing to compare the differences in speed, frequency and access and egress times. Using the outcomes of the bus line comparison, relations that determine integration can be assessed. Two significant relations for characteristics that influence integration have been found, being the speed of the service (commercial speed) and the frequency of the service.

A stop based comparison allows to consider elements from the environment that influence travel choice and integration. Three assessment have been conducted, the assessment of spatial levels, the assessment of activities, and the assessment of type of bus stop (access or egress). A regression analysis has shown that there is a relation between the spatial level (1 for extremely urbanised, 5 for rarely urbanised) and the catchment area of the bus stop. The directions of these relations are different for Comfortnet and R-Net. For Comfortnet, the catchment radius increases when the spatial level decreases, for R-Net, this is the other way around. The assessment of activities has shown no significant relations. The final assessment, the type of bus stop, has shown that for access stops, people travel longer distances by foot (not that this is the activity based side), probably because of the lack of availability of other modalities. On the egress side (home-based), distances for egress stops are shorter than for non-classifiable stops.

Step 3: Development of Optimisation Alternatives

The previous steps have shown that two characteristics contribute to an increase in integration. For two bus lines in Amstelland-Meerlanden, one Comfortnet line and one R-Net line, alternatives are developed to determine the influence of the identified characteristics (integration) on the effects of the systems. For the Comfortnet line, six alternatives are considered (base alternative, frequency increase, speed increase, decrease in stop density, speed and frequency, and finally speed, frequency and stop distances). For the R-Net line, three alternatives have been generated (the base alternative, the express service alternative (skipping stops) and the tunnel alternative (allowing for a higher service speed)).

Step 4: Modelling of Alternatives

The different alternatives are modelled and assessed using a traffic model. The traffic model used is the transit model of VENOM, the regional model of Stadsregio Amsterdam. OtTransit is a class of OmniTRANS that is used for two main purposes: the assignment of traffic to the network, and the generation of transit costs (skims). The model has first been validated for use. By comparing the number of passengers (Qlik data of March 2015) with the modelled number of passengers, the model is validated based on outcomes. By comparing the usage of bus stops (GOVI data) with the usage of bus stops in the model, the behaviour of the model is validated.

Step 5: Assessment of Effects

The different alternatives are modelled and compared. This comparison allows for the calculation of total travel times, using the previously mentioned total travel time equation and the equations for the catchment area. This leads to the travel times as presented in Table 29. These travel times will be used in a Cost-Benefit Analysis (CBA) in step 6 to compare the effects of the different alternatives. The assessment of effects has also shown that when the characteristics that influence integration are altered, the number of passengers increases.

Step 6: Comparison of Systems

The performance of the different alternatives, in terms of travel time and number of passengers, is done using a Cost-Benefit Analysis (CBA). This CBA allows to assess the alternatives on societal viability by taking into account both the costs of implementation of these alternatives (e.g. operational costs, implementation costs), as well as the benefits (travel time savings, increase in operational income through the increase in number of passengers). This analysis shows that for line 172, the frequency alternative and the speed alternative give a positive outcome. For line 300, both developed alternatives are positive, but the express service alternative has shown a tremendous increase in monetise benefits as compared to the base scenario.

Conclusion and Recommendations

The research question of this thesis has been stated as follows:

What are the main characteristics of the transport system and its environment that influence transport network integration, how do these characteristics relate to differences between conventional bus systems and high quality bus systems, and how can these characteristics be captured in a framework that assesses integration effects of the entire transport chain?

This research question is answered in three different steps. The first of the research question, *'What are the main characteristics of the transport system and its environment that influence transport network integration'* can be answered with the fact that bus line characteristics influencing integration have been identified, being commercial speed and frequency, and two environmental characteristics, being the spatial level around the stop and the typology (access of egress) of the stop, that influence the catchment area, and as such the integration of the system. With large qualitative competitive characteristics that drive the success of R-Net as a high quality bus service (speed, frequency), the catchment area of a stop is positively influenced: the competitive advantage of the system as a result of these characteristics makes that people travel longer distances to a stop (and as such answers the second part of the research questions *'How do these characteristics relate to differences between conventional bus systems and high quality bus systems')*. Catchment radius around high quality bus stops (R-Net) is much larger than that for conventional lines (Comfortnet), both for walking as well as for cycling access and egress links.

The final part of the research questions *'How can these characteristics be captured in a framework that assesses integration effects of the entire transport chain'* has been answered by the incorporation of the three identified prerequisites into the framework. With the framework, integration can be assessed, both by the analysis of different characteristics of the different bus lines, as well as by the comparison of different bus lines belonging to different types of bus services (e.g. conventional lines and high quality lines). Furthermore, the framework allows to go even deeper into the understanding of integration, by not only analysing characteristics responsible for integration, but by also assessing the effects of altering these characteristics to allow for improved integration in the entire trip chain. As such, the framework is capable of assessing and identifying characteristics responsible for integration, as well as assessing the effects of the transport system. Apart from these scientific contribution of the framework, the framework is also useful for concession authorities and public transport operators to help assess the performance of their bus system, and to help indicate which characteristics could be improved in order to create a positive CBA outcome that benefits both the concession authority as well as the passenger.

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1. Introduction

Changes in spatial and demographic aspects of society influence the demand for transportation. Furthermore, the political environment and financial constraints impose limitations on the construction of new infrastructure. As such, there is a call for smart transport solutions through the optimisation of existing networks and services. Together with the focus on integration of different transport systems, these smart solutions contribute to the development of networks where seamless trips are possible. This research presents the development of an assessment framework which allows for the assessment of transport network integration. With this framework, the integration of different bus systems with Non-Motorised Transportation (NMT) access and egress modalities can be assessed. Non-Motorised modalities include walking and cycling. Although a lot of research has been carried out that addresses the assessment of integration of NMT as access and egress modalities with rail networks (especially in the Netherlands), less is known about the integration of bus networks with NMT. This research tries to fill that knowledge gap by developing an assessment framework for transport network integration. With this framework, the causes and effects of integration in bus networks can be identified, and this framework allows for the comparison of integration for different types of bus networks. This chapter introduces the problem at hand, and presents the objective of this research. The scope of the research is presented, and the research methodology and thesis outline are discussed.

1.1 Problem Analysis

Transportation plays a crucial role in the establishment of economically strong regions and countries. Changes in technology, demographics, societal preferences, urbanisation and travel patterns have led to an increase in transport demand and distances travelled (Guequirre, 2003). The design and priorities of transport systems are driven by the needs, preferences and desires of the population of a region, the so called 'demographic drivers'. The expected increase in welfare, employment, and the number of one-person-households, will increase the demand for transportation up to 2040 in the Netherlands (Rutten, 2010). Together with the expected increase of the population in urban regions (Department of Economic and Social Affairs, 2014 revision) this calls for smart solutions to facilitate supply for the growing demand of transport services in urban regions.

Even though new transport links could increasingly meet the growing demand resulting from an increase in population, financial and spatial aspects put constraints on improving networks through the supply of new, costly ways of transportation. Instead, there is a need for the optimised use of existing networks and services. This includes optimising existing networks through integration and upgrading existing bus services to high quality bus services, which are less costly than implementing (light) rail alternatives (Covero & Dai, 2014). The idea of integration is explained in more detail in chapter 2. Integration entails *the combination of individual elements of the transport chain, from a travellers' origin to its destination, with the aim to positively influence the performance and effects of the transport system. This combination entails the integration of the different elements through improvement of the performance of mode specific characteristics that influence integration, taking into account the environment of the entire system.*

Improvement starts with involving the entire chain of transportation instead of focusing on just one part of the trip, by facilitating integration between different transport modalities (e.g. walking and the bus) to allow for a variety in travel options. However, integration of the different modalities needs to be seamless: transfers between modalities have to be easy and efficient. Although a lot of research has been carried out that focusses on the comparison of (light) rail alternatives and bus services, and the relation of integration between rail services and non-motorised transportation (NMT) as access and egress modalities (especially in the Netherlands), a lot less is known about the effects of integration of bus networks with NMT access and egress modalities. This includes insight in the characteristics of the transport system that influence integration, as well as insight in the differences in effects between high quality bus systems and conventional bus systems. For instance, high quality bus systems have higher speeds and frequencies than conventional bus systems, but to reach these benefits, stops are positioned at larger distances from one another. This influences the choices for access and egress modalities by users of the bus system.

From the previous paragraphs, it can be concluded that two issues exist:

- There is a societal need for smart transport solutions through the upgrading of existing bus systems. This issue will be addressed in the section 'societal relevance'.
- There is a lack of scientific knowledge of the causes and effects of transport network integration over the entire transport chain, thus including access and egress modalities (walking and cycling) and the dominant bus link. This issue will be addressed in the section 'scientific relevance'.

1.1.1 Societal Relevance

Growing transport demand, caused by an increase in population, welfare and employment, puts pressure on existing transport infrastructure. Research has shown that in the large urban region in the western part of the Netherlands (the Randstad) accessibility within the region lacks behind and should be improved (Organisatie voor Economische Samenwerking en Ontwikkeling, 2007). Constructing new infrastructure is often costly, and planning of infrastructure asks for a lot of preparation time. This could be seen as the 'tragedy' of infrastructure: planning is time intensive, and infrastructure is built for a relatively long asset life time (Slebos, 2015). This makes infrastructure rather inflexible: it is difficult to directly respond to changes in society (demand), due to the long planning time for new infrastructure, and the longevity of existing infrastructure. Furthermore, decisions about transport investments (e.g. the construction of infrastructure) are influenced by the political climate. Changes in government (as the result of elections) causes changes in political agendas and decision making.

Rutten (2010) advocates that the use of existing infrastructure through targeted upgrades is a more efficient way for tackling these issues. Using existing infrastructure can be seen as a flexible approach to deal with the trend of urbanisation. Upgrading existing conventional bus networks to high quality bus networks is one of such approaches. From a societal point of view, it is important to gain insight in the effects of the utilisation of existing (bus) infrastructure to meet growing demand. Integration provides a way to efficiently use existing infrastructure. This research focusses on bus networks and non-motorised transportation, hence it is important to gain insight in effects (costs and benefits) related to network integration for the entire transport chain of NMT and bus networks, both for users of the systems (travellers), as well as for the concession authorities and operators of the system. Furthermore, gaining insight in the differences in integration between conventional and high quality bus systems helps in the decision process when a trade-off between conventional bus systems, high quality bus systems, and (light) rail systems has to be made. NMT-modalities provide flexibility on the access and egress sides of (inflexible) public transport services (Kager, 2015), and with the increasing usage of the bicycle as an access and egress modality for train trips, it is beneficial to determine if the bicycle can offer the same flexibility in access and egress for bus trips.

1.1.2 Scientific Relevance

A lot of research has been carried out that compares high quality bus services with light- and heavy rail public transport options (Brown & Thompson, 2009), which all stress the cost-effectiveness of high quality bus systems over rail systems. A lot less is known about the comparison between conventional bus services and high quality bus services, and the possible benefits arising from upgrading to high quality services. Furthermore, the research carried out to assess the effects of upgrading bus networks on access and egress modalities (walking and cycling) is limited. Even more so, research for access and egress integration predominantly focusses on integration with rail networks.

Although a lot of literature can be found on how transport networks can be integrated, there is no consensus amongst the different literature on how integration can be assessed. Where some sources assess integration from a spatial aspect (Hickman, Seaborn, Headicar, & Banister, 2010), others stress the policy integration side through analysis of costs and benefits of transport networks (Punzo, Torrieri, Borzachellio, Ciuffo, & Nijkamp, 2010). Furthermore, the lack of assessment methods results in a shortage of knowledge into the characteristics of the transport system that influence integration. Because of the many ways in which transport network integration can be assessed, it is important to develop a method that assesses transport network integration based on the performance of the entire system, by observing and analysing different aspects of integration and characteristics of the transport system to fully gain insight in the affiliated effects.

1.1.3 Problem Statement

The lack of extensive research and literature availability, together with the societal need for the efficient use of existing transport infrastructure results in the need for more insight in:

- The effects of bus network upgrading to high quality services on the entire transport chain through comparison of BRT-systems and conventional bus systems;
- The causes and effects of network integration in Bus-NMT transport systems;
- A way to assess the performance of the entire transport chain as the result of transport network integration, considering the interaction of the transport network with its environment.

Combining the scientific and societal relevance leads to the problem statement of this research:

Problem Statement

The pressing need for the efficient use of existing transport services, together with the existing lack of research into the integration of the networks of busses with NMT, calls for insight into the causes and effects of network integration in Bus-NMT transport systems, including differences between conventional and high-quality bus services, and the consequences of the upgrade of conventional bus systems on transport network integration and performance of the system.

1.2 Research Objective and Research Questions

This report aims to fill in the knowledge gap that exists in the transport world today. The choice of design of the bus network influences the choices for access and egress modalities. However, which design characteristics influence integration and to what extent are unknown. Optimisation of public transport networks does not only involve optimising the dominant (public transport) link in the transport chain, as spatial and demographic characteristics of the environment of the transport network influence design choices. This research aims to develop a framework to assess the causes and effects of an integrated bus-NMT network, including the differences between conventional and high quality bus systems. This includes the effects resulting from an interaction between the network and its environment.

1.2.1 Research Objective

To be able to address the three issues presented in section 1.1.3, a framework, with which transport network integration can be assessed, has to be developed. Deriving from the problem analysis, the research objective can be stated.

Research Objective

To develop an assessment framework with which characteristics of the transport system that influence transport network integration can be determined, through the assessment of the performance of different types of bus services and their NMT access and egress modalities.

1.2.2 Research Question

Addressing the problem statement and the research objective results in the following research question:

Research Question

What are the main characteristics of the transport system and its environment that influence transport network integration, how do these characteristics relate to differences between conventional bus systems and high quality *bus systems, and how can these characteristics be captured in a framework that assesses integration effects of the entire transport chain?*

This research question requires a more elaborate explanation. *'Characteristicss'* of importance include characteristics of the transport system, as well as characteristics that result from the interaction of the transport system with its environment, including spatial and demographic composition. The *'effects'* that are researched are not endless in nature. The effects of upgrading the networks researched here all entail design-specific effects like total travel time (from origin to destination, taking into account access, egress, waiting, and in-vehicle times) and travel demand (expressed in number of passengers). To be able to answer this research question, different sub-questions have been developed that partially answer the main research question. These sub-questions are presented and explained in section 1.4, together with the methodology and outline of the report.

1.3 Research Scope

1.3.1 Involved Modalities

As explained in the previous sections, this research involves four different types of modalities that can be divided in two network groups. The groups and modalities of importance for this research are:

- Bus Networks:
    - Conventional Busses;
    - High Quality Busses.
- Non-Motorised Transportation Access and Egress Networks:
    - Walking;
    - Cycling.

Other modalities, including train, tram and metro networks, might also be considered in this research, but not to the extent of detail as the four modalities mentioned above. These modalities are only researched in the context of contribution and added value to network integration, and are not considered as modalities for which design and integration is assessed.

1.3.2 The Transport Chain

The integration of the networks follows from the multi-modal nature of (single) trips. Multi-modality implies that different modes of transportation are used to reach a destination (D) from an origin (O), through a transfer node (T) where the passenger transfer from one modality to another. Unimodality, on the other hand, means that for the entire transport chain one mode is used to get from the origin to the destination. In this research, the focus lies on walking or cycling as access and egress modes, and the bus as the transit service in a multi-modal transport chain, as depicted in Figure 2.

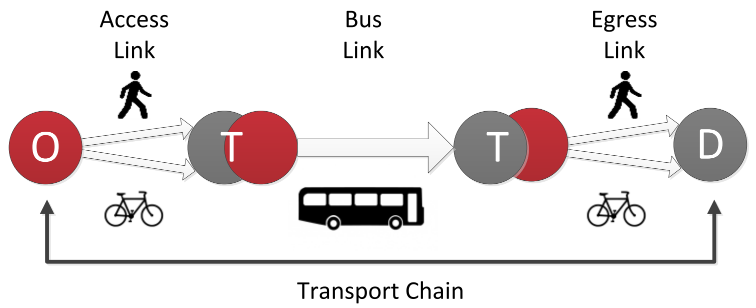


Figure 2: Representation of the Multi-Modal Network (Transport Chain)

1.3.3 Network Characteristics

To be able to analyse and compare the networks under consideration, the effects of the networks and their integration are assessed. This assessment involves different steps, as will be explained in more detail in chapter 4. Effects of the network derive from the performance of the network, which can be assessed through network specific characteristics. Since the list of characteristics is limitless, it is important for the sake of this research to explain which types of characteristics are included in this research.

For the analysis of the different networks (access and egress NMT and bus systems) modal specific characteristics are used. Furthermore, since spatiality and demographics are important factors that influence travel behaviour (see also chapter 3), these factors need to be assessed as well. Hence, two types of characteristics will be assessed in this research:

- Network specific characteristics, including speeds, stop densities, line densities and frequencies;
- Network environment characteristics, including spatial characteristics and demographics.

The quality of public transport networks can be defined in many different ways. This research does not quantify qualitative aspects of public transport in terms of comfort, travel information and cleanliness of the vehicles and bus stops. However, other measures of quality of service are of importance. This predominantly includes network design characteristics like stop densities, frequency, service reliability, and travel time. The characteristics and effects that are assessed and compared using the framework are explained in more detail in chapters 3 and 4.

1.4 Methodology and Outline of the Report

In order to answer the research question of section 1.2, a research methodology has been developed. This section gives insight in the different steps that have been taken during the course of this research to answer the research question. Furthermore, the research question is split in several sub-questions that are addressed in the different chapters of this thesis. Figure 3 presents the research methodology. As can be seen, the methodology exists of four different steps.

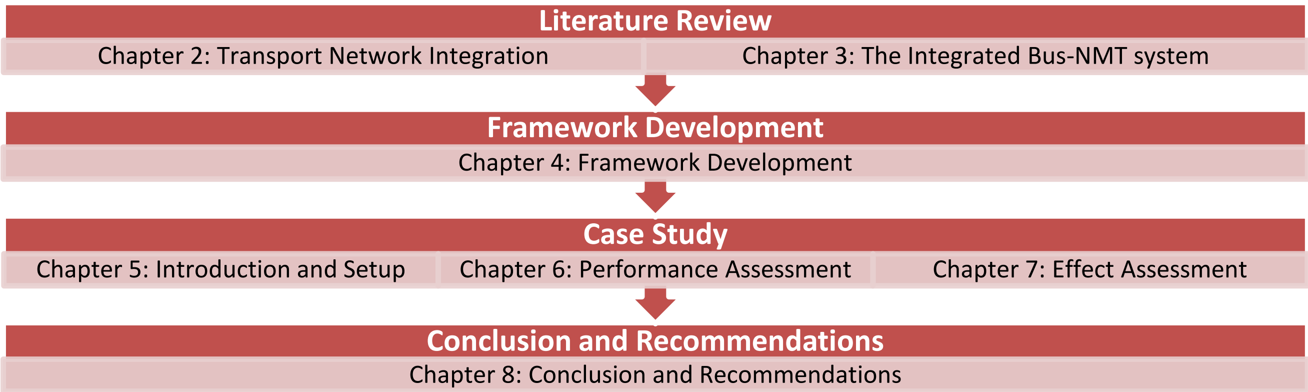


Figure 3: Outline of the Report

1.4.1 Literature Review

To be able to develop the framework, literature has to be consulted first. This literature analysis is divided into two steps. First, the general concepts of transport network integration are explained in chapter 2. Next, as this research deals only with integration of NMT access and egress modalities with bus services, chapter 3 presents a discussion of integration in bus systems. This also includes a literature review of the different elements of the integrated bus system. These two chapters contribute to the development of the 'building blocks' of the assessment framework and as such give insight in the transport characteristics that need to be considered when assessing integration.

Chapter 2: Transport Network Integration

1. What types of transport network integration can be distinguished, and which definition of transport network integration is used in this research?
2. What challenges exist for transport network integration?
3. How can transport network integration be assessed?

Chapter 3: The Integrated Bus-NMT System

4. What elements can be identified in the integrated bus-NMT network?
5. Which characteristics of elements that could potentially influence transport network integration in bus networks should be considered in the framework?

1.4.2 Framework Development

With the consideration following from the previous part the framework can be developed. This framework, as explained earlier, has to be able to assess transport network integration, the influence of integration of the effects of the system, and the differences between conventional bus services and high quality bus services. Chapter 4 gives an overview of the considerations that need to be taken into account, as discussed in chapter 2 and 3, translates these consideration into a framework.

Chapter 4: Framework Development

6. Which considerations need to be taken into account for the development of the assessment framework?
7. How can the different elements of the transport system, including their specific characteristics, be captured in one assessment framework?
8. Which characteristics of the elements of the transport system are assessed with the framework?

1.4.3 Case Study

The case study is used to test the framework and to assess integration in a concession area of Stadsregio Amsterdam. To be able to use the framework, data requirements have to be stated first (chapter 5). With the framework, the elements and their characteristics of the concession area under consideration (Amstelland-Meerlanden) that influence integration can be identified (chapter 6). Finally, chapter 7 provides insights in the way the effects of the system are influenced by changes in the performance of the system.

Chapter 5: Case Study: Introduction

9. Which data is needed for the case study?

Chapter 6: Case Study: Performance Assessment

10. Which specific characteristics (e.g. network design) of elements influence network integration?

Chapter 7: Case Study: Effect Assessment

11. How does integration influence the effects of the transport network?
12. What conclusions can be drawn from effect assessment for the systems under consideration in the case study?

1.4.4 Conclusion and Recommendations

The final step of this research involves answering the research question by presenting the conclusions of this research and listing recommendations for future purpose. These conclusions and recommendations are presented in chapter 8. By answering the different sub-questions, a final sub-quesution can be ansered before the answer to the main research question is discussed.

Chapter 8: Conclusion and Recommendations

13. To what extent is the framework useful for performance assessment in practice?

2. Transport Network Integration

To fully understand the concept of integration and its importance, this chapter discusses transport network integration in more detail. Different definitions of transport network integration are discussed, and the general definition used for this research is presented. Implementing transport network integration in existing or new networks proves to be difficult. Hence, the challenges of integration are discussed. Finally, this chapter presents the status-quo of assessing integration, and discusses different approaches of assessment.

2.1 Definition of Transport Network Integration

Transport integration can be described as *'The organisational process through which the planning and delivery of elements of the transport system are brought together, across modes, sectors, operators and institutions, with the aim of increasing net social benefits using different levels and different definitions'* (NEA, OGM, & TSU, 2003). Givoni and Banister (2010) argue that integration is important when a system consists of different parts, and where the different parts need to complement each other for the system to work efficiently. The system under consideration in this research also consists of several parts, which have to be integrated in such a way that it ensures a seamless trip for the passenger. A trip can be seen as a chain of transportation (Zuidgeest, et al., 2009) from origin to destination, where the links of the chain represent different parts of the trip, often different modalities. Figure 4 gives an example of a transport chain where the access mode is the bicycle, the next link in the chain is a bus trip, and the egress mode is walking. Transfer from one modality to another takes place in transfer nodes.

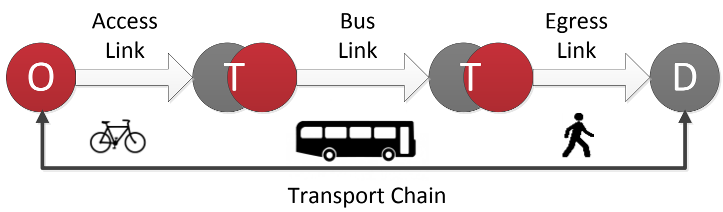


Figure 4: Multi-Modal Transport Chain

The integration of individual modalities follows from the multi-modal nature of (single) trips. A trip, in contrast to a tour, is a movement from an origin to a destination. A tour on the other hand can consist of multiple trips, and always ends where it started. Different definitions of multi-modal trips exist. Where Van Nes (2002) describes a multi-modal trip as *'two or more different modes that are used for a single trip between which the traveller has to make a transfer'*, Hoogendoorn-Lanser (2005) describes multi-modality as the use of more than one transport service for making a trip, *'being a combination of private and public transport services or a combination of public transport services'*. Multi-modality is a frequent arising phenomenon in public transport trips. Because of the inflexible nature of public transport services (resulting from its reliance on infrastructure, timetables and routes), other modalities are often used as access and egress modalities (Kager, 2015).

Due to the variety in travel options, a traveller will have different means and different configuration possibilities for the trip. Figure 4 illustrates travel options with three modalities. A traveller, however, could also opt for a single-modal trip, for instance by bike or by car. The decision for the trips and the individual links are based on characteristics of the entire chain (integration), as well as on characteristics at the link- and node-level. A commonly used way of understanding the choices of travellers is through utility maximization, where a traveller will try to reach as large of a utility as possible given different attributes (characteristics) of alternatives of the trip (Muizelaar, 2011). The combination of characteristics and utility derived from this, could, for instance, imply that a passenger opts for a trip of cycling-bus-walking, instead of a faster cycling-bus-train-bus-walking trip, should the traveller experience a disutility from the transfers that is higher than the possible utility of a faster trip. Hence, integration does not only involve optimisation at link level, but should also entail optimisation in the location where the two links meet, as well as optimising the combination of these different parts.

According to Ibrahim (2003), four types of transport integration exist:

- Physical integration, which entails seamless trips, where transfer facilities (between modalities) are improved;
- Network integration, where different hierarchical levels of the transport system are integrated by adapting the characteristics and performance of the individual levels, hence connecting different modalities;
- Fare integration, where an integrated ticketing system over the entire network is provided;
- Information integration, where information for all modalities is available.

This research predominantly focusses on the second type of integration; network integration. For network integration to be reached, physical integration has to be addressed as well. This research thus also involves integrating the different modalities at the physical level. This research focuses on the location of integration, hence physical characteristics of transfer facilities related to this location are of importance (e.g. exact location, catchment area). As such, this research focuses on the first two types of transport integration: physically integrating the networks through the different transfer facilities (physical integration) and accordingly integrating the bus network with NMT access and egress (network integration). However, it is too simplistic to consider the entire system as just the combination of the individual modal links. Integration also involves taking into account the environment of the transport system. Hence, the entire system involves environmental aspects that influence the individual transport links and the entire transport system. Environmental characteristics, like spatiality and demographics, provide the opportunity to assess the networks in perspective of its surrounding. Insight in work- and residential locations, the number of inhabitants and the 'potential' of the area (in terms of potential passenger numbers for the service offered) also influence network design through demand. As such, both spatial and demographic characteristics of the environment of the transport network have to be considered as well.

To summarise, the definition of transport network integration that is used in this thesis is the following: *Transport Network Integration is the combination of individual elements of the transport chain, from a travellers' origin to its destination, with the aim to positively influence the performance and effects of the transport system. This combination entails the integration of the different elements (modalities) through improvement of the performance of mode specific characteristics that influence integration, taking into account the environment of the entire system.*

2.2 Challenges of Transport Network Integration

Integrating different networks to form a fully integrated transport system is not easy, and is subject to challenges that have to be overcome. First of all, integrated networks are multi-modal networks. The dominant position of the train in multi-modal trips has generated a plethora in research into the integration of access and egress with rail networks, especially in the Netherlands. Research into the integration of bus network is lagging behind. According to Givoni and Banister (2010) three challenges of transport network integration can be identified:

- Transport considerations need to be integrated in the policy process. This entails identifying the location of activities that generate demand (multi-modality);
- Supply of transport needs to be integrated by focussing on the trip from origin to destination rather than on the dominant modality (mismatch demand and supply);
- The different institutions responsible for the transport network and operations need to work together (transport considerations in the policy process).

In research transport network integration is very often researched from the policy level and perspective. The policy perspective takes a view point from a higher level, but fails to incorporate operational aspects on a detailed level. Little research has been carried out for the actual strategic side of network operations, relating to traffic volume and mode of travel (Hickman, Seaborn, Headicar, & Banister, 2010).

For this research, the first two challenges are of priority. The last challenge will only be discussed in terms of a societal cost benefits analysis that considers the travellers and the responsible transport institutions (operators and concession authorities). In the following sub-paragraphs, the three challenges are discussed in more detail, and approaches to identify demand to adapt supply are presented. Another important challenge of transport network integration that has to be addressed involves different design dilemmas of the system. This challenge will be addressed in more detail in chapter 3.

2.2.1 Multi-Modality

According to KIM (Kennisinstituut voor Mobiliteitsbeleid, 2014), a multimodal trip is a trip where at least two different modalities are used. However, walking to a car, and using that car from origin to destination is considered as unimodal, even though walking in part of the trip chain. Figure 5 shows the share of multi-modal trips in the Netherlands. Although only 3% of all trips is multi-modal in nature, 13% of all travelled kilometres in the Netherlands (2.6 billion kilometres) are multi-modal of nature. Thus, it can be concluded that, since the share in number of trips is small but the share of total kilometres is large, multi-modal trips are used to travel longer distances. Figure 5 also shows the dominant position of the train in multi-modal trips. This can explain the dominance of the train in multi-modal transport research. The share of the bus as the dominant modality is 14%, still a large percentage, and thus justifies the need for more insight in to integration of multi-modal trips with the bus as the dominant modality. Figure 5 shows the average of the entire country of the Netherlands. However, when looking more closely at a more densely populated region of the Netherlands, the share of multi-modal trips, and the share of kilometres travelled using multiple modalities increases, as can be seen in Figure 6.

Thus, the conclusion can be drawn that in highly urbanised regions, the share of trips and kilometres travelled using more than one modality is higher than in more rural regions. This once again stresses the need for smart transport solutions: with increasing urbanisation and travel demand expected to grow in the coming years, there is a need for smart, reliable, multi-modal travel options. The multi-modal chain where the train is the dominant modality has been researched extensively. The bus however, being the dominant modality in 14% of all multi-modal trips, needs to be researched more to fully understand bus network integration with NMT as access and egress modalities.

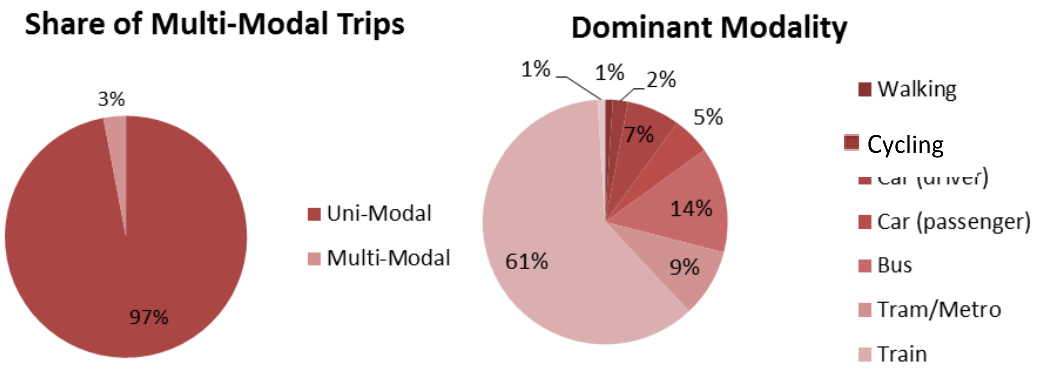


Figure 5: Multi-Modal Trips in the Netherlands (Kennisinstituut voor Mobiliteitsbeleid, 2014)

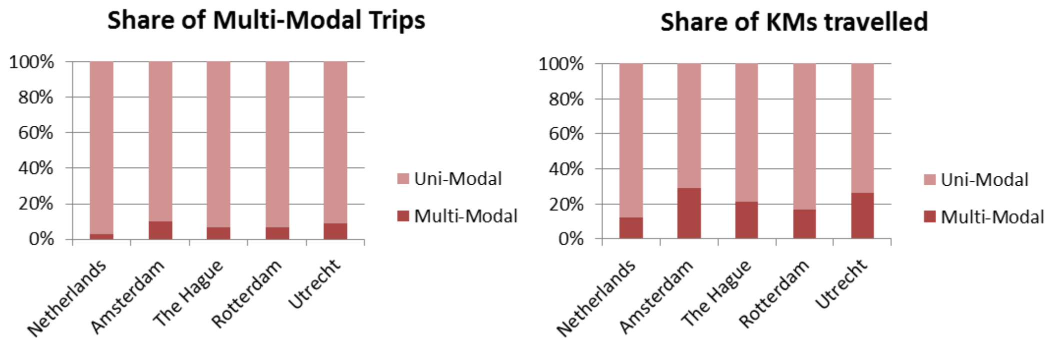


Figure 6: Multi-Modality in High-Urbanised Regions (Kennisinstituut voor Mobiliteitsbeleid, 2014)

Of course, people not only travel within cities and agglomerations. When looking at relations between different regions, the following shares are highest: between different urban regions (not to urban centre)(13%), between city centres (16%), and from urban region to a city centre (14%). Again, this stresses the use of multi-modal trips for longer distances. This can also be seen in the fact that although the share of multi-modal trips on the total number of trips made has not changed much over the years, the total kilometres travelled in multi-modal trips has changed: from 10 to 13%.

2.2.2 Mismatch Demand and Supply

In the past, upgrading and optimising transport systems has often only involved a focus on the dominant transport modality. The idea of the entire transport chain, from origin to destination, is often forgotten in policy making and research, and is often caused by the fragmented structure of governmental institutes (multiple departments and hierarchical 'policy layers'.). This fragmentation results in a lack of insight in efficiently optimising transport networks. Givoni and Banister (2010) illustrate this by stating there is a mismatch between demand and supply. Though passengers (demand) make a choice of mode and network based on the overall journey and consider all elements of this journey, on the supply side, however, the multi-modal aspect of trips and journeys is often overlooked and only involves a focus on single-modal trips. Thus, due to mismatch, costs of the transport system increase. Efficient transport systems can reduce costs in terms of travel times (passengers) and capacity (supply) meeting demand. Offering integrated transport services will reduce the costs and inconvenience of travel (Ibrahim, 2003).

Bakker et al. (2010) explain that modelling supply is more complicated for public transport than for other modes. One of the most important characteristics of public transport services causing this complication is the existence of an operator. The opening of, for instance, a new motorway (Bakker, Koopmans, & Nijkamp, 2010) will automatically give travellers the possibility to travel by offering supply for other modalities. However, for public transport infrastructure services, especially in markets where the infrastructure administration and operations of the network are separated, use of infrastructure can start later or are operated less frequently than initially intended. Another difficulty of modelling supply is that it is not sufficient to model supply with just zones and links. Where for other modes, the length of the link (travel time or distance) represents travel resistance, for public transport services resistance exists of much more than just travel time and distance. Aspects like waiting time, comfort and the availability of accurate travel information contribute to the overall experienced resistance.

2.2.3 Transport Considerations in the Policy Process

As explained in chapter 1, financial aspects, amongst others, put constraints on addressing the transport issues by implementing new, costly infrastructure. Instead, governmental institutes are searching for ways to address transport issues through the better, more efficient use of existing infrastructure. Transport investments are paid for by tax payers' money, which means expenditures always have to be motivated. When implementing the efficient use of existing infrastructure, a political trade-off has to be made.

Krizek and Stonebraker (2010) state that effectively integrating the network of the bicycle with public transit will lead to an increase in the catchment area of the transit service, an increase in the efficiency of the transit service through the reduction of the need for local bus lines, and an increase in the overall demand for cycling. Especially the increase in efficient use of the transit service is of importance for this research. Krizek and Stonebraker argue that through the reduction of the need for local bus lines by providing a cycling option, efficiency will increase. However, one should not forget about people with reduced mobility, who often heavily rely on local transportation.

Activities and locations generate demand. Through the optimisation and integration of the transport system, supply and demand can be matched better. However, this improved transport system will come with a cost. As Krizek and Stonebraker (2010) state, improved integration might reduce the reliance on local bus services, and hence increase the use of high quality systems. This decreased reliance on local lines might be an incentive to cancel bus lines where expenses are higher than profits generated through demand and use of the lines. However, there seems to be a growing opposition to this efficiency-thinking. Public transport in less populated areas has social benefits that apparently are not taken into account anymore (Slebos, 2015), for instance the position of the bus as a means for 'social accessibility' for people without a car. Hence, deciding which lines could be discarded based on demand and supply issues is not as straight forward as one might think: a political trade-off has to be made. Although Dutch political decisions state that accessibility through transport networks should be provided for Dutch citizens, budget cuts in exploitation contributions from the National Government have decreased tremendously over the years. As such, governmental institutes responsible for the exploitation of the public transport system have a limited budget to cover 'empty chairs' in public transport (Van Der Meulen, 2015), making it difficult to motivate continued investments in unprofitable bus lines.

Although these political trade-offs are important when considering transport projects that help improve transport network integration, this research does not focus on these trade-offs in detail. In this research, the framework assesses the causes and effects of transport network integration for bus systems, and thus does not give insight nor advice on how to address the political trade-off issues for integration. However, results from this research could help identify characteristics that can be altered to improve transport network integration. Hence, for the policy making process, this research provides a mean to governments to underpin transport policy choices based on insight in the working of integration in bus networks.

2.3 Assessing Transport Network Integration

When trying to understand the way integration works in different systems, and when trying to explain the effects of integration, it is important to be able to assess different transport networks. Although a lot of literature can be found on how transport networks can be integrated, there is no consensus amongst the different literature on how integration can be assessed. Where some sources assess integration from a spatial aspect (Hickman, Seaborn, Headicar, & Banister, 2010), others stress the policy integration side through analysis of costs and benefits of transport networks (Punzo, Torrieri, Borzachellio, Ciuffo, & Nijkamp, 2010). Because of the many ways to assess transport network integration, it is important to develop a method that assesses transport network integration by observing and analysing different aspects of network performance. Furthermore, literature does exist on the comparison of different (types of) bus lines. However, there is no framework or methodology to asses and compare bus network integration with NMT.

Assessing transport network integration proves to be difficult. Especially when it comes to actual planning, development and governance of the transport system. Integration is difficult to define, analyse and implement (Givoni & Banister, 2010). This can also be seen from the many different ways transport integration is assessed in literature. Transport models are very often used from the perspective of assessing demand and as such meeting supply. However, these models focus on the dominant modality rather than on (integration of) the entire chain. Research and modelling approaches to assess integration do exist, albeit fragmented. Where one research focusses on integration by optimising the dominant transport mode, another focusses on the optimisation within transfer stations (the bus stop). The next paragraph gives a brief overview of existing ways to assess and analyse transport network integration.

2.3.1 Integration through Nodal Points: Physical Integration

A lot of research has been carried out that assess the quality of the transfer point in multi-modal transport networks, thus the location where the different networks meet. Ibrahim (2003) identifies this as physical integration: ensuring seamless trips through the improvement of transfer facilities. This is done both from an operational perspective (in terms of actual waiting times and integration with the time table) as well as from a behavioural or preference individual perspective. From the operational perspective, waiting times and integration with the timetable (through minimising dwell times and allowing for transfers), are most important to optimise to ensure transport network integration. Another important aspect in this approach is the existence of (guarded) bicycle parking near the stations and stops of public transport networks (Rietveld, 2000).

Although this last mentioned type of physical integration has been research extensively, this part of integration is not the focus point of this research. Integration in this research comprises of so much more than just ensuring integration at the point where the two networks meet. For this research, the performance of the entire transport chain is assessed. Hence, performance parameters like the mentioned waiting time in transfer points is of importance for this research. Another characteristic of the transfer points that is of importance is reliability. All transport characteristics will be discussed in more detail in chapter 3, chapter 4 discusses which characteristics are included in the assessment framework.

2.3.2 Integration through Societal Analysis and Policy Making

Another approach used to assess integration is by analysing the societal effects of transport policies. This approach of assessment is in line with the focus of integration from a policy rather than an operational perspective. Though operational factors, like travel times and fare prices, are taken into account when determining the societal effects and thus the effects of policy making, this approach does not give the level of detail that is needed to determine the differences between conventional and high quality bus services, nor does it involve identifying the characteristics that influence integration.

Example of approaches where integration is based on a policy and societal perspective rather than a network perspective are researches by John Preston (Preston, 2010), who has developed a framework based on environmental, safety, economic and integration factors to assess policies. Punzo et al. (2010) use a cost-benefit analysis to assess the integration of transport networks after a possible construction of a metro line in Venice. This research does focus on operational integration of transport networks, and not solely on integration of policy and transport networks. Hence, though again certain aspects of societal analysis and policy making analysis methods are of relevance for this report, an approach based on societal analysis only is not sufficient to assess effects of operational network integration.

2.3.3 Integration through Network Analysis

Zuidgeest et al. (2009) have developed a way to assess the effects of transport integration by combining aspects of trip-making characteristics and urban system indicators. This approach is in line with this research: by assessing modal-specific characteristics and spatial factors, Zuidgeest et al. provide a tool to assess the effects of integration over the entire network. This approach identifies a list of transport characteristics, with which the effects of integration are determined to help optimise network design. However, this approach is one step ahead: to fully understand transport network integration, the actual way these characteristics influence each other and integration has to be assessed first. That integration has certain effects is clear, but it is important to identify characteristics that influence integration. Zuidgeest et al identify the causes of integration, but skip the step where the actual way characteristics influence integration is explained.

This approach starts with identifying different factors that influence integration, and are important from the perspectives of different actors (the passenger, the operator and the community). Next, these characteristics are combined in two different groups: trip-making characteristics (e.g. trip length, travel time, travel costs), and urban system indicators (e.g. service area, population, cycle network). These so called indicators of integration can be used to generate spatial measures which are planning support indicators for urban transport systems. Next, Zuidgeest et al. present a modelling framework that represents the transport system. However, as stated before, this method skips the step where the strength and direction of influence of characteristics on integration are assessed. More importantly, this method gives an estimation of effects, but does not necessarily explain the occurrence of the effects and the possible improvement of network integration. Hence, this method gives a way to assess integration, bus not to score integration or explain how integration occurs and how it can be improved. This is what is needed in the transport field: a framework that can assess the strength and direction of relationships between transport network characteristics and integration.

2.3.4 A Combination of Methods: Transport Network Integration

Although the three methods discussed in the previous sections assess different aspects of transport network integration, none of the methods fully captures the entire concept of integration. As explained in section 2.1, transport network integration is: *the combination of individual elements (links) of the transport chain, from a travellers' origin to its destination, thus combining different transport networks in one system, with the aim to positively influence effects of the transport system. This combination entails the integration of the different links through improvement of mode specific characteristics that influence integration, taking into account the environment of the entire system.*

The first assessment method discussed (physical integration), only captures the '*combination of individual elements*' on the nodal level. Optimising integration at the network level (optimisation of the different modal-links and integration between these modalities), is not captured. The second method (policy making) only assesses the effects of network integration (in the decision making process), but does not give insight in the individual characteristics of the system contributing to transport network integration. The final method (network analysis) does discuss the different characteristics and parameters of the transport system, but gives no insight in how to actually score and compare integration based on these characteristics for different networks.

Hence, a combination of the three different assessment methods, together with extra added steps, is needed to fully understand integration. These steps include gaining insight in:

- The influence of network specific characteristics on transport network integration;
- The influence of the integrated transport system on effects;
- The assessment and comparison of different systems in terms of performance characteristics and effects.

To enable this full assessment of the integrated transport network, which includes the previously mentioned steps, a framework has to be developed that eases assessment and gives insight in the level of integration and possible characteristics that can be adapted to increase integration and optimise the transport network. This framework will be discussed and presented in chapter 4.

2.4 Conclusion

In this chapter, the concept of transport network integration has been presented. With the insights from this chapter, three questions, as stated in chapter 1, can be answered:

Question 1: What types of transport network integration can be distinguished, and which definition of transport network integration is used in this research?

Four types of transport network integration can be distinguished:

- Physical integration, which entails seamless trips, where transfer facilities (between modalities) are improved;

- Network integration, where different hierarchical levels of the transport system are integrated, hence connecting different modalities;
- Fare integration, where an integrated ticketing system over the entire network is provided;
- Information integration, where information for all modalities is available.

This research focusses on physical integration (ensuring seamless trips through the provision of efficient transfer facilities), and network integration (seamlessly connecting networks of different modalities). Furthermore, combining these two types of transport network integration, together with multi-modal characteristics of the transport chain, has led to the following definition of transport network integration:

Transport Network Integration is the combination of individual elements of the transport chain, from a travellers' origin to its destination, with the aim to positively influence the performance and effects of the transport system. This combination entails the integration of the different elements (modalities) through improvement of the performance of mode specific characteristics that influence integration, taking into account the environment of the entire system.

Question 2: What challenges exist for transport network integration?

This chapter presented several more general components that prove to be challenges that have to be dealt with, which can influence transport network integration. These challenges are:

- Concept of multi-modality in integrated networks and the importance of multi-modality for travelling longer distances;
- The mismatch between demand and supply, where it is important to not only focus on the dominant modality when generating supply, but integration through observing the entire transport chain is key;
- The difficulties of transport consideration in the policy process, where a trade-off between efficiency, accessibility and the social function of transportation has to be made.

Question 3: How can transport network integration be assessed?

Section 2.3 introduced three different assessment methods for transport network integration. These are:

- Integration through assessment of nodal (transfer) points;
- Integration through assessment of societal analysis and policy making;
- Integration through network analysis.

However, as has been addressed, these three assessment methods fail to capture the entire concept of transport network integration. Where the first integration method fails to assess integration at the network level, the second method only assesses the effect of network integration bus does not explain how characteristics of the system influence these effects. The third method discusses these characteristics but fails to give insight in how to actually score and compare integration based on these characteristics for different networks. For this research, a combination of these three, with the addition of extra assessment methods, is needed to fully grasp transport network integration. This results in insight needed in three different aspects to be able to assess transport network integration:

- The influence of network specific characteristics on transport network integration;
- The influence of the integrated transport system on (societal) effects;
- The assessment and comparison of different systems in terms of performance characteristics and effects.

How these three aspects can be included in the framework will be discussed in chapter 4. The framework provides a means to an end to assess transport network integration by both assessing the network itself, as well as assessing the influence the network has on its environment (societal effects).

3. *The Integrated Bus-NMT System*

The previous chapter explained the meaning of transport network integration. Although in theory, integration could be assessed and researched for every multi-modal kind of trip, this research solely focusses on transport network integration of bus networks and NMT access and egress modalities (walking and cycling). This chapter presents the integrated transport system for this research, discusses the different elements of this system, and presents the different modalities of the system in more detail.

3.1 The Integrated Transport System

For the purpose of this research, it is important to describe the integrated transport system and its components, relationships and influencers. To do so, it first has to be clear what a 'system' exactly is.

3.1.1 Definition of a System

A system can be described as '*a collection of elements that is discernible within the total reality*' (Veeke, Ottjes, & Lodewijks, 2011), meaning that the different elements have mutual relationships and relationships with elements from the environment. These elements have '*attributes*', which are the properties of the elements. Relationships between the elements indicate an interaction between these elements, meaning '*the characteristics of one element can change the values of the characteristics of another element and vice versa*'. The system is positioned in '*the total reality*', and influenced by elements from this total reality, which together comprise the '*environment*'. Elements from the environment influence values of characteristics of elements from the system, or are influenced by the system. Finally, the '*emergence*' of a system is '*the principle that whole entities (groups of elements) display characteristics that are only meaningful when they are assigned to the whole and can not be reduced to the individual elements*'. These are the 'emergent characteristics' of the system, or the effects. The next paragraph explains these different facets of 'the integrated transport system'.

3.1.2 The Integrated Bus-NMT system

Figure 7 presents a simplification of the integrated transport system. This figure does not show how integration is reached, but gives an overview of the different parts of the system that could potentially influence integration. These include:

A. The Transport Chain

As presented in chapter 2, the transport chain presents the entire trip from origin (O) through the access node (AN) and egress node (EN), using the bus link, to the destination (D). The system boundary represents that the elements of the transport chain (see the next sub-section) are part of the system.

B. The Spatial and Demographic Elements

The spatial and demographics elements are outside boundary of the system of the transport chain, and are elements from the environment of the system, that influence the system. Although these environmental elements are not part of the transport chain, they are drivers of the system, and determine the effects of the system.

C. The Effects of the Integrated Transport System

These effects are the 'outcome' of the system, both for travellers (e.g. total travel time) as well as for society (e.g. emissions) They present the outcomes of the system, and are the 'system emergence', which are characteristics of the system (in this case the outcome) that can not be reduced to the individual elements of the system and their characteristics.

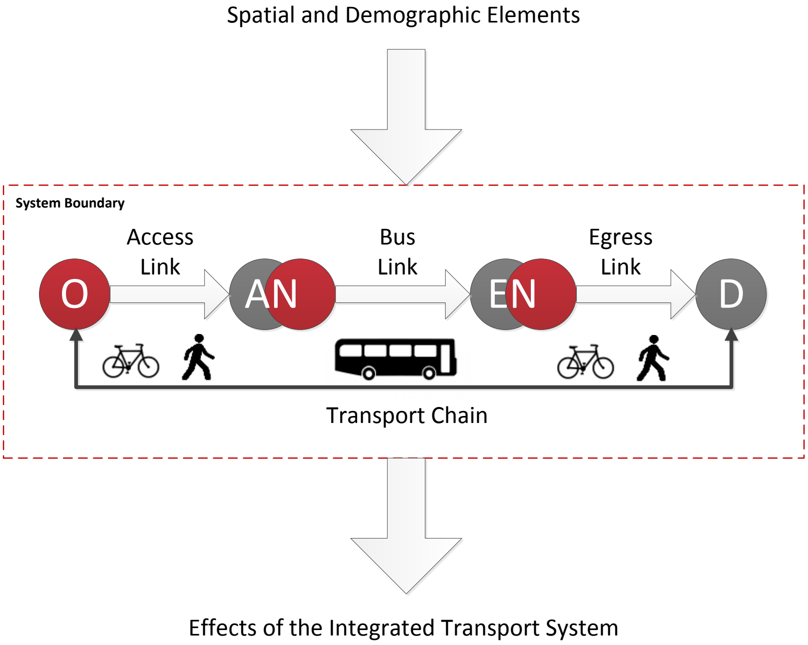


Figure 7: The Transport System

System Elements

Figure 7 presents the entire integrated transport system for this research. The integrated transport system consists of different elements, being:

- The access link;
- The access node;
- The bus link;
- The egress node;
- The egress link.

Each of these elements has their own characteristics that are measurable and can thus be compared. Note that for this research, the 'integrated system' is related to one type of bus service or one type of bus line. This implies that conventional bus services, thus individual lines, are assessed separately from one another and separately from high quality bus lines, in order to provide for the possibility to compare the systems. As explained, the elements have attributes, or characteristics. Examples of attributes of the bus link are in-vehicle times, stop distances and frequencies. These attributes all have a certain value, and thus can be measured and compared the values of the same attributes of other elements (e.g. a comparison between access and egress modalities), or of other entire integrated systems (e.g. the comparison of two bus lines in the same area). These different characteristics influence transport network integration and thus have to be assessed to determine which characteristics exactly influence integration and to what extent. More information about attributes of these elements, their value and how they can be assessed can be found in chapter 4.

An example of a relationship between the different elements is the way the waiting time within the element 'access node' is influenced by the 'access link' and the 'bus link'. For instance, someone who walks to the bus stop, might arrive too early, and has to wait longer than when the access time (the time it takes to get from the origin to the bus stop) would have been better tuned to the arrival time of the bus. This waiting time will also be influenced by the bus link, in terms of frequency of the service and punctuality. These relationships will be explained in section 3.3.

System Environment

The environment of the integrated transport system influences the attributes of the individual elements. There are two important types of environmental elements that are considered for this research: spatial elements and demographic elements. Both these types of elements influence the demand of the transport service. For example, areas that are scarcely populated (spatiality) generate less demand than high urbanised regions, and different age groups (demographics) have different travel preferences. Furthermore, spatial constraint physically limit the construction of transport infrastructure. Hence, these two environmental elements are considered. Chapter 4 describes which characteristics of these elements are considered in the framework.

System Emergence

Finally, the emergence of the system describes that the system may display certain characteristics (or in this study effects), that can only emerge and or only meaningful when these characteristics are assigned to the whole of the system. To summarise: these effects can not be reduced to individual elements of the system. This statement is rather abstract. To give an example, the number of passengers is an effect of the system that can not be reduced to merely the characteristics of the dominant bus link. Instead, this effect is the result of the combination of elements of the system, in this case access, egress, bus link, and environmental characteristics, together with characteristics outside of the scope of this research (e.g. personal preferences, travel comfort and fare prices). The effects of individual lines can be compared to assess the result of integration on the entire bus network in a region. Chapter 4 describes these in more detail. Another example of an effect is the total (weighted) travel time from origin to destination. This travel time consists of access time, waiting time in the access node, in-vehicle time in the bus link, and egress time, which in turn are influenced by other characteristics of the transport system. The way the different elements are integrated determines the eventual size of the effect.

3.2 Non-Motorised Access and Egress Links: Walking and Cycling

Non-Motorised Transportation, walking and cycling, are analysed in this thesis from the perspective of access and egress modalities in the transport chain. The reach (or catchment area) of access from origin to the bus stop and of egress from the bus stop to the destination differ per modality. Non-motorised modalities (or slow modes) have a significantly smaller range (or reach) than motorised transport, since this type of transportation involves a certain amount of physical effort (Krygsman, Dijst, & Arentze, 2004). However, the nature of NMT, walking and cycling, make that these modalities are rarely used for longer trips, although the emergence of the E-Bike might change this. At the ends of the trip (access and egress) walking and cycling allow for a high variety in options: both are not bound to spatial constraints. The con of walking and cycling is the short distance that can be covered.

The nature of the access and egress modalities influence the catchment area of public transport services (Bovy, Van der Waard, & Baanders, 1991). If the access and egress sides of public transport, in terms of time or distances, exceed a certain threshold, a traveller will no longer opt to use the public transport service (Krygsman, Dijst, & Arentze, 2004). Hence, when analysing multi-modal transport trips, it is important to take the characteristics of access and egress modalities into account (e.g. reach, time and distance).

3.2.1 Walking and Cycling

Walking is often not considered as a separate modality, since it is a universal component, both at the start and end of a trip (Van Nes, 2002). However, to analyse the access and egress modalities of public transport, and to ensure integration of NMT and public transport services, walking is important to consider. Especially since walking has a large share in access and egress modalities. Because of the importance of walking in integrated networks in combination with its universal nature, it is important to define walking as a modality in integrated networks. One must note that the walking part between transfers of two public transport services (e.g. walking to a connecting bus or train) is not considered as a separate modality. In this research, the focus lies on walking or cycling as access and egress modes, and the bus service (Conventional or BRT) as the transit service. All other uses of walking and cycling apart from access and egress modalities in public transport trips are outside of the scope of this research.

The Netherlands is known all over the world for its highly developed and widely used bicycle (infrastructure) network. One could argue that since the existence of the bike is taken for granted in the Netherlands, the insight into drivers for cycling and explanatory research are slim. But to ensure highly integrated public transport networks, cycling, as an important access and egress modality in the Netherlands, has to be analysed and researched in more detail. The bicycle, like walking as a modality, is highly flexible and has a high penetration rate in urbanised regions. As such, the bicycle is a complementary modality to public transport networks. Where the bike can be used for shorter distances with a need for flexibility, public transport can be used for longer distances. The reach of the bike (in terms of distance travelled or time) could increase given a (new) introduction to the market of the bicycle: the electric bike, or E-bike. The E-bike could influence these distances, but can also influence the type of passengers opting for the bicycle as access or egress modality: the reduced need for physical effort to cycle could persuade the elderly or less mobile people to use the bicycle.

3.2.2 Access versus Egress Modalities

Krygsma et al (2004) identify walking and cycling as dominant access and egress modes, and explain that these modalities are sensitive to spatial characteristics (land use), environmental conditions (weather), and the travel distance. To ensure fully integrated transport networks, these factors on the access and egress side of the trip have to be taken into account in network design. According to Krygsman et al. (2004) differences in access time and egress time exist for the comparison of walking and cycling. At the access side, time for walking and cycling is considered to be similar: the extra time to cover a distance through walking is compensated for the extra time spend at a station/stop for parking and locking the bike. On the egress side, the bicycle is used to cover longer distances. Krygsman et al. calculated that on the access side, people are willing to walk 500m and cycle 1.8 km, while on the egress side they accept walking distances of 600m and cycle distances of 2.4 km. Krygsman et al. conclude that the bicycle is not a substitute for walking when time is of importance, but indicates that travellers accept longer access and egress times with a faster mode.

In the Netherlands, especially in the cities, the bicycle is the number one access and egress modality for train trips. Although exact shares of bicycle usage in the transport chain with the bus as the dominant modality are unknown, the shares for train as the dominant factor have been researched thoroughly. Figure 8 illustrates the modal split of access and egress modalities to and from the train.

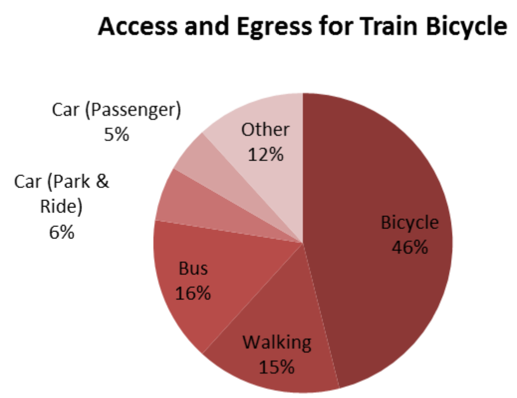


Figure 8: Access and Egress Modalities for the Train (Kennisinstituut voor Mobiliteitsbeleid, 2014)

Of course, the use of modalities differs per side of the transport chain, thus access and egress can be different modalities for the same trip. Figure 9 illustrates the share of modalities on the access side (left) and egress side (right) in Amsterdam for train trips.

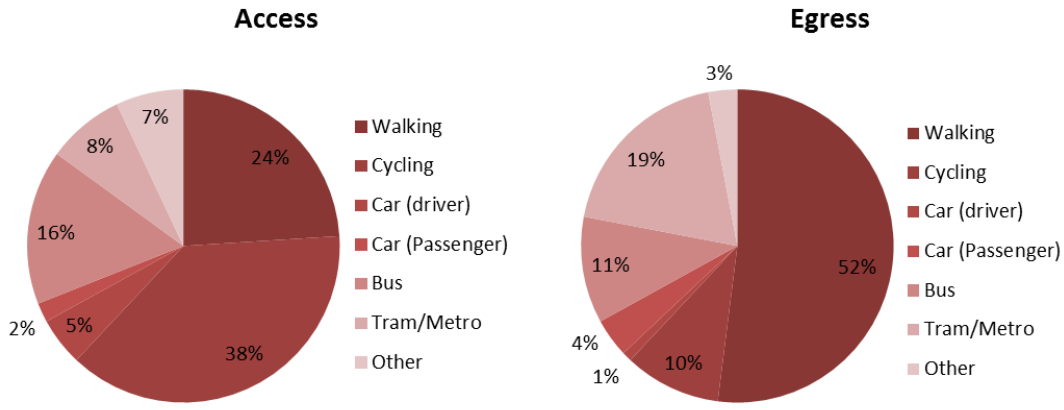


Figure 9: Access and Egress Modalities in Amsterdam

The most important difference between access and egress modalities is the change in share of walking and cycling. Where walking has a share of 24% on the access side, it has a very large share of 52% on the egress site. The opposite is true for the bicycle: the share decreases on the egress side, with 38% for access and 10% for egress. These shares indicate that people will travel shorter distances on the egress side, since the reach of a stop is smaller for walking. One would expect a similar pattern for bus journeys (high cycling on the access side, high walking on the egress side). For busses, the dominant access and egress mode is walking. Almost 25% of all multi-modal trips exist of walking links on the access side (similar to the access to trains stations). The research by Kennisinstituut voor Mobiliteitsbeleid (2014) has shown that for busses, the bicycle plays a really small role on the egress side, since private bikes or bike-share options are rarely available on the egress side of bus stops. This provides a chance for further research, as there might be potential for bike-sharing systems to increase flexibility of the trip on the egress side.

3.2.3 Design of Access and Egress Networks

Improving the access and egress sides of the transport chain holds a great potential to improve the public transport part of the trip chain. Improving access and egress influences transport trip time and proves to be a valuable option for improving the entire trip chain as opposed to expensive vehicle and infrastructure improvement alternatives within the public transport part of the chain (Krygsman, Dijst, & Arentze, 2004). The importance of ensuring integration of public transport with its access and egress modalities is stressed by many researches; access and egress are the weakest parts of the transport chain, and disutility is experienced from access and egress (Bovy & Jansen, 1979).

Land-use (see paragraph 2.6) is an important influencing factor of the quality of access and egress networks. Access and egress modalities are predominantly walking and cycling. The distance to the location of the bus stop influences the use of public transport: longer distances on the access and egress sides reduce the change for people opting for public transportation (Krygsman, Dijst, & Arentze, 2004). Thus, one effect of transport integration that has to be analysed is the influence of spatial structure on access and egress modalities. This also includes analysing demographic characteristics at the bus stop catchment area level. Demographics determine travel motives, e.g. home-work based trips, or home-social based trips.

However, one should take into account that the reach (catchment area) of a public transport service not only depends on the access and egress sides: waiting times at the public transport stop, in-vehicle times and fare prices are also important aspects that determine the choice for public transport. Krygsma et al. (2004) also stress this: the catchment area of public transport networks also relies on the relative share of the total trip time, and not merely on the access and egress times.

3.2.4 Strengths, Weaknesses, Opportunities and Threats of Access and Egress

The strengths, weaknesses, opportunities and threats of NMT access and egress have been discussed in the previous sections. Table 1 presents a summary of these SWOT's.

Table 1: SWOT Access and Egress

	Strengths	Weaknesses
Non-Motorised Transportation	• Flexible; • High variability in travel options (not bound to spatial constraints); • High penetration rate in densely urbanised regions • Complementary to long-range modalities.	• Only for shorter distances (small reach); • Slow; • Limited to a certain threshold.
	Opportunities	Threats
	• Development of the E-Bike; • Bike-sharing systems on the egress side of trips; • Allow for a greater variety in trips and destination given the right integration with public transport services.	• Heavily dependent on weather conditions; • Often not considered in the optimisation process of public transport.

This SWOT gives the chance to identify possible pitfalls of walking and cycling as access and egress modalities. For instance, the slow nature of walking and cycling as compared to motorised transportation makes that these modalities are predominantly suitable for short trips. However, the flexible nature of these modalities together with their high penetration rate in urbanised regions makes these modalities an interesting option to compete with bus services that are depended on time tables and infrastructure. Both as a replacement for bus services, as well as a complementary modality to (higher level) bus services.

3.3 Bus Link

Busses provide (public) transportation using road infrastructure. Busses are rubber-tired, steered vehicles that operate on streets in mixed traffic (Vuchic, 2007), though some bus systems operate on (partially) separated, exclusive infrastructure. Busses can be used for different types of services: from short haul-service in urban city centres to long-haul international bus services. Usually, bus services operate in accordance with a timetable, specifying frequencies and headways.

3.3.1 Conventional Bus Systems

Review of literature (Vuchic, 2007; Tyler, 2002; Givoni & Banister, 2010; Brown & Thompson, 2009) has resulted in a short summary of the characteristics of conventional bus systems. Busses provide a form of flexibility in terms of dependency on infrastructure and penetration rate. As opposed to other public transport systems, busses do not rely on dedicated infrastructure like (light) rail networks do. Furthermore, due to the fact that busses use road networks for their services, they will have a high penetration rate into high urbanised, densely populated regions. Busses are less costs-intensive due to their use of existing road infrastructure, and rerouting and changing operations is easy to do. However, the reliance on infrastructure is also a shortcoming of bus systems. Due to an increase in car traffic, chances of congestion influencing operations are high. Furthermore, from a traveller perspective, busses can be inflexible, since they operate in accordance with a certain timetable and follow a specified route. This influences the choice of origin, destination and routes of travellers. Bus services are restricted to capacity, and with demand likely to increase due to urbanisation, lack of capacity is a major threat for bus systems. Other public transport services, like metro services and long-haul rail services, can provide higher frequencies, higher capacities and longer distances in shorter amounts of time.

3.3.2 High Quality Bus Systems

Opportunities for bus services all relate to possible upgrading to higher quality services. Higher frequencies can help with increasing capacity, and upgrading is easy and cost-effective due to the fact that the new bus service will use existing infrastructure. High Quality Bus Systems, or Bus Rapid Transit (BRT) essentially are bus systems higher in hierarchy than conventional systems, upgraded through network design (stop densities, speeds, line densities) and network service.

High Quality Bus Networks have been implemented around the world, using different names for the same type of transit service. This difference terminology for the same system is important in the search for relevant literature, and consists of the following names (Deng & Nelson, 2011):

- Bus Rapid Transit;
- High-Capacity Bus Systems;
- High-Quality Bus Systems;
- High-Level Bus Service;
- Metro-Bus;
- Surface Metro;
- Express Bus Systems;
- Busway Systems.

Many definitions of BRT systems exist. Definitions range from strict separation between BRT and modalities that use road infrastructure, to more integrated networks where BRT and other road users share the road, or are simply separated by means of a dedicated bus lane. Levinson et al. (2002) capture the essence of BRT in such a way that it leaves space for interpretation, hence ensuring that different high-quality bus systems can be classified as BRT. The definition of Levinson et al. is the one used in this research, to ensure a broad description of the term. In doing so, this leaves the opportunity to identify and define the specific characteristics of the BRT system in a case study (see chapter4). They describe BRT systems as follows:

'BRT is a flexible, rubber-tired transit mode that combines stations, vehicles, services, running ways, and ITS elements into an integrated system with a strong positive image and identity. […] BRT is a permanently integrated system of facilities, services, and amenities that collectively improve the speed, reliability and identity of bus transit. In many respects, BRT is rubber-tired light rail transit (LRT) , but with greater operating flexibility and potentially lower capital and operating costs.' (Levinson, Zimmermann, Clinger, & Scott Rutherford, 2002). Table 2 presents the most common characteristics of BRT systems.

Table 2: BRT Characteristics

Characteristic	Description (adaptation from Sedler (2014) and Levinson et al. (2002))
Roadways	Vehicles can operate in all kinds of traffic using different kinds of infrastructure (e.g. mixed traffic lanes, bus lanes, dedicated bus lanes), where the level of mixing determines the relative increase in -speed, reliability, and identity.
Stations	BRT stops resemble tram stations rather than conventional bus stops and have an easily recognizable design (e.g. level boarding platforms, design of stops and shelter).
Rolling Stock	BRT vehicles are designed to improve comfort (e.g. low-floor buses), speed and safety. They have distinctive designs, colours and graphics.
Service	The system offers fast, regular and reliable high-frequency services.
Ticketing	BRT offers fast and efficient ticketing through the use of the national OV-Chipkaart (Public Transport Chip Card).
ITS	Using digital technologies to improve comfort, speed and reliability, as well as safety for passengers, drivers and planners (e.g. vehicle location systems, signalised intersections, controlled tunnel approaches).

McDonnel and Zellner (2011) adapt a more policy minded –instead of infrastructure minded- view when describing BRT as *'road-based policy measures that aim to increase the priority and, therefore, the performance of bus services'*. They stress, like Levinson et al., that BRT exist in many forms (e.g. high frequency, exclusive bus lanes), and that the combination of the road-based policy measures intend to increase the attractiveness of BRT, eventually influence a modal shift to BRT. The interesting perspective from McDonnel and Zellner, as opposed to other literature, is that the authors specifically mention the use of existing (bus) infrastructure for BRT services, where (minor) adaptations are allowed.

3.3.3 High Quality Bus Systems versus Alternative Transit Systems

A lot of research has been carried out that compares BRT systems with Light- and Heavy rail infrastructure (Brown & Thompson, 2009), which all stress the cost-effectiveness of BRT systems over rail systems. A lot less is now about the comparison between conventional bus services and BRT. As opposed to the conventional bus network, BRT networks could offer higher value due of operations and service resulting from the distinctive characteristics of BRT. These characteristics can increase ridership. Currie and Delbosc (2011) identify the following improvements from conventional bus services to BRT services that can increase ridership:

- The higher frequency of bus services with longer operating hours;
- The bus priority systems (e.g. segregated right of way), which reduce journey times and improve service reliability, thus dedicated infrastructure are a means to increase reliability;
- Improvement in the definition of networks and corridors, branding and information provision, which will ease the understanding of the system for the traveller.

The most stressed benefit of BRT as opposed to other transit systems is the financial advantage, in terms of operational costs, construction and maintenance. However, Zuidgeest et al. (2009) also make the comparison with BRT and other mass rapid transit system from the feeder perspective. They state that mass transit services, and in particular BRT, heavily depend on local systems, like the conventional bus, due to the lower density of the BRT systems in terms of line density and stop density. Thus, BRT will never replace conventional systems fully; they will rely on conventional, local bus services to be able to offer a high quality public transport network in the entire region under consideration. However, with the growing importance of the bicycle as a 'local' system for train trips, the bicycle could also prove to be the local system for bus networks.

3.3.4 Design of Bus Networks

Public transport networks have to be able to facilitate the growth in demand from the agglomeration (a chain of villages, towns and cities) to the economic heart of urbanised regions. The current patterns in urban and regional public transport are limited by financial, spatial and demographical constraints. This calls for a change in the existing planning approach, by opting for targeted investments to increase the quality of existing facilities instead of creating new infrastructure and transport networks. However, the multi-modal aspect of trips is often overlooked, and needs to be incorporated in planning, design and policy making of (public) transport networks.

Rutten (2010) argues that better use of the existing public transport systems in the Randstad is a solution for optimisation of the transport system. Better use of existing infrastructure could prove to be beneficial for the trends and constrains as identified earlier. Upgrading existing networks can increase capacity, thus meeting demand, while costs are lower as opposed to constructing completely new transport networks (including new infrastructure). Furthermore, better use of existing transport networks means less need for using scare space, since transport connections and infrastructure are already available.

Literature Review of Bus Network Design

As explained in section 3.3.3, ridership is an effect of the transport network (number of passengers). Studies that assess how ridership in BRT systems can be improved have been carried out by Hensher and Golob (2008) and Currie and Delbosc (2011). Characteristics that influence ridership can give more insight in the integration of transport systems, as the composition of these characteristics determines the effects of the transport system. Hensher and Golob (2008) have compared 44 BRT systems world-wide to identify which characteristics influence ridership. The research concludes that four factors have a significant impact, being:

- The number of stations;
- The headway during peak hours;
- The trunk vehicle capacity;
- The fare of the service.

Most important is to note that this research implies that more stations increase ridership. However, more stations, leading to a higher stop density, could influence the speed of the service in such a way that it no longer is distinctive from conventional bus services, and BRT loses its advantage of high-speed services, and is no longer distinguishable from conventional services. The research unfortunately gives no implications for the trade-off between vehicle speed and number of stops.

Currie and Delbosc (2011) researched the BRT features which influence route-level ridership. They observed several previous studies of BRT systems. The results however, have to be interpreted with some caution: important factors that might have an influence on ridership have not been assessed, including vehicle capacity and fare structure. Currie and Delbosc identified the following features of BRT that influence ridership:

- Services levels. Which are expressed in terms of frequency, span of hours covered and vehicle kilometres on a route;
- Spatiality. Employment density of an area influences ridership;
- Average speed of the system;
- Share of segregated right of way;
- Vehicle accessibility.

The average speed is a peculiar finding. The research shows that speed negatively influences ridership. Currie and Delbosc draw the conclusion that high ridership cause slower speeds rather than vice versa. Another factor is vehicle accessibility. However, Currie and Delbosc conclude that this factor represents a large range of influences of which the cause and effect on ridership is unknown. A notable factor for this research is the integration of the BRT network with other systems. Currie and Delbosc noticed that the Sydney T-Way BRT system experienced low ridership levels resulting from poor urban design and poor walk accessibility to bus stops. Hence, Currie and Delbosc stipulate the importance of network integration for ridership gains. They conclude that this integration includes both integration with the wider transit network, as well as integration with street access into urban developments through stop catchment.

Factors of Optimisation

Solely focussing on the optimisation of the dominant part of the chain, the public transport service, will have several effects that influence the efficiency of the service. However, as stated before many times, efficiency of a system can be higher when integrated with other networks. Though, to understand optimisation, this paragraph presents the factors influencing optimisation and the effects of this optimisation for public transport networks.

From the previous paragraph, public transport network can be optimise by solving the problem of the mismatch between demand and supply when it comes to ridership. Bakker et al. (2010) identify the following aspects (factors) that influence the supply side and thus need to be taken into account when solving the mismatch problem:

- The density of the bus stop service area, which determines the access and egress times and distances;
- The frequency of the service, which determines the waiting times;
- The intervals between the services, equal intervals will make it easier to remember the departure times;
- Walking times during transfers
- Reliability, which determines the need to add time margins to the trip planning (from the passenger point of view);
- Comfort in the vehicles, stations, and at bus stops;

- Parking around the facilities (bicycle parking, car parks);
- Ease of using the system: ticketing, reservations, timetable.

However, the list as composed by Bakker et al. is rather focussed from the perspective of the traveller, and thus seems to fall a bit short when trying to explain the mismatch between demand and supply from a more generic perspective (for both the passenger as well as the operator).

Janic (2014) gives a better overview of this. Two other important factor that seems to be forgotten by Bakker et al. relate to the actual supply and operations of the system:

- Capacity of the line, which depends on the in-vehicle capacity and the maximum number of vehicles which can pass through a fixed point (location) in a given time period.
- Speed, which consists of two different types:
    - Operating speed, which depends on the vehicle, traffic and infrastructure design, and comprises of acceleration, deceleration and cruising.
    - Commercial speed, which includes the operational speed, but also takes into account dwell times at bus stops.

These are all factors that influence the performance of the system, and thus can be used when optimising the dominant public transport side of the transport chain. However, optimisation of public transport networks does not only involve optimising the dominant (public transport) link in the transport chain. Optimisations of the public transport networks starts with involving the entire chain in the analysis, thus ensuring network integration. Hence, to be able to address the need for smart transport solution, integration of public transport networks with its entire chain is of crucial importance, thus including walking and cycling (Non-Motorised Transport, NMT) as access and egress modalities in the analysis.

Design Dilemmas

In order to facilitate the use of existing infrastructure to make the transport system more efficient, the different elements of the transport system, as well as their whole (the way they work together) has to be optimised. The previous two sections discussed different characteristics of the bus system that can be adapted to optimise the bus network. However, there are several dilemmas in this optimisation: optimising one characteristic will reduce the positive effect of another characteristics. Both (Tahmasseby , 2009) and (Van Oort & Van Nes, 2009) discuss these different dilemmas. Table 3 presents the dilemma and the trade-off that has to be made.

Table 3: Design Dilemmas (Tahmasseby , 2009; Van Oort & Van Nes, 2009)

Design Dilemma		Trade-off	Explanation
High stop density and short access time	Low stop density and longer access times	Short access time versus short in-vehicle time	More stops reduce the access time, but the operational speed of the system decreases
High network density and low frequency	Low network density and high frequency	Short in-vehicle times VS short waiting times	Both these dilemmas imply that when the network is denser (more lines) the frequency goes down
High line density and low frequencies	Low line density and high frequencies	Minimisation of transfer versus short waiting time	
Large number of services with large number of transfers	Small number of services with small number of transfers	Minimisation of transfers versus short travel times	This dilemma implies that more services will increase the need for a transfer due to a fragmented network coverage.
Long lines and lower reliability of service	Shorter length and higher reliability	Minimisation of the waiting time versus direct lines and number of transfers needed	When travelling in the same direction, longer lines can be beneficial since they reduce the need for transfers, however, long lines reduces the reliability of the service

These trade-off need to be taken into account when considering integration of the bus network. Increasing stop densities on a line can positively influence the in-vehicle time, but can increase the access and egress distance. Hence, these design dilemmas have to be taken into account in this research.

3.3.5 Strengths, Weaknesses, Opportunities and Threats of the Bus System

The strengths, weaknesses, opportunities and threats of the bus system have been discussed in the previous sections. Table 4 presents a summary of these SWOT's.

Table 4: SWOT Bus System

Bus Systems	Strengths	Weaknesses
	• Flexible in terms of reliance on infrastructure (can use the same infrastructure as the car); • High penetration rate as opposed to rail; • Low investments costs; • High diversity in route options due to flexibility; • Rerouting is fairly easy.	• Congestion when operated in mixed traffic; • Capacity constraints; • Subject to regulations in terms of vehicle design and service operations; • Threats to the environment (air pollution, noise pollution); • Non-flexible in terms of route options for passengers due to dependency on routes and timetables.
	Opportunities	**Threats**
	• Upgrading to higher hierarchical systems using existing facilities is cost-effective; • Higher frequencies to offer higher quality services; • Improve accessibility through integration with land-use; • Decrease congestion and demand for capacity of infrastructure through the provision of dedicated bus infrastructure; • Increase in service through bus-priority at intersections.	• Capacity shortage due to increase in demand (urbanisation); • Decrease in performance (speed, reliability) due to crowed road network; • Weak identity and image; • Other public transport services can carry more people over longer distances in shorter amounts of time • Network design (e.g. stop densities) will influence ridership.

As was the case with the SWOT for access and egress modalities, this SWOT gives insight in to the short falls and successes of bus systems. For instance, the bus performance is highly influenced by other traffic on the same road when no dedicated infrastructure is present. This influence the speed of the system and the reliability. With the SWOT analysis, different aspects that can either limit or improve integration from the view point of bus links can be identified (chapter 4).

3.4 Access and Egress Nodes: Integration of Networks

The final elements of the integrated transport system itself are the nodes where the different networks meet. The reach, or catchment area, of such a node has already been discussed in the previous two sections. This is because the reach is not only influenced by the position of the bus stop (or node) in the spatial and demographic surroundings (the environment), but is highly dependent on the two discussed transport networks (bus and NMT). Characteristics of access and egress nodes predominantly involve safety, the accessibility of the bus stop and the waiting time and waiting conditions at the stop.

Two of these mentioned characteristics are not discussed further in this research. These are safety aspects and waiting conditions. Waiting conditions include the quality of the bus stop and the quality of the information offered at the bus stop. As this research focusses on the integration of the different modalities from a network performance perspective rather than a service perspective, the two characteristics of accessibility and waiting time are important. Accessibility for this research is described as the 'ease with which the bus stop can be reached from an origin', expressed in either distance or travel time. Long waiting times at the bus stop, for instance due to a low frequency of the service or low reliability (see section 3.3), influence the entire trip time. One could state that seamless trips in high integrated networks have waiting times that are as low as possible. The effects of network integration, of which total trip time is one, is explained in more detail in chapter 4.

3.5 Environmental Elements: Spatiality and Demographics

Land-use (spatial and demographic characteristics) plays an important role in transport networks: the spatial characteristics around the bus stop location can increase or decrease the catchment area of the transport service depending on the density, diversity and layout of the spatial structure (Loutzenheiser, 1997). Different studies have shown that the influence of the public transport services declines with an increased distance to the stop. Land-use and transport systems are closely linked an influence each other, since the patterns of land use and the different facilities all directly influence travel generation (Potter & Skinner, 2000), thus the demand for travel. Hence, it is important to take these elements from the environment of the system into account when assessing the integration of transport networks.

3.5.1 Spatial Structure

Urban concentration, higher densities, and functional blending of space and activities in urban areas could reduce travel distances (Maat, 2010), resulting in people opting for more sustainable means of transportation like the bicycle, instead of the polluting option of the car. Furthermore, urban concentration can increase the public support and use of public transport services. However, the tendency towards urban concentrations comes with a cost, since urban concentration puts a lot of pressure on existing transport networks (Rutten, 2010).

Ewing and Cervero (2001) have developed the three D’s for considering the relationship between the spatial structure and the transport networks:

- Distance between origin and destination
- Density of the area
- Diversity of the area, in terms of mixture of urban functionalities.

They argue that short distances between origin and destination, high building density and a high mixture of urban functionalities reduces the reliance on the car, and will increase the number of people who opt for modes like walking, cycling and public transit. Thus, these three D’s show how the spatial structure influences the use of different modalities. For the situation of the Netherlands, KIM (Kennisinstituut voor Mobiliteitsbeleid, 2014) stresses that the differences between cities with different aspects (three D’s) is not that large as should be expected. This can be explained by the fact that the three D’s and their effects are only visible when the area of observation is small enough, thus when analysing boroughs, neighbourhoods and districts instead of entire cities. This level of analysis, an aspect of spatiality, has to be taken into account when analysing the integration of transport networks.

The three D’s have been redeveloped and replenished many times. Cavero has added two more D’s, being Design and Destination Accessibility (Cervero, Sarmiento, Jacoby, Gomez, & Neiman, 2009). Figure 10 shows the different factors influencing travel behaviour, from which other aspects of spatiality that influence the transport system can be derived.

Resulting from the 5D’s and the framework from Figure 10, Hickman et al. (2010) have developed a list with 11 themes that have to be covered when analysing the relation and thus possible integration of spatial structures and the transport network, as presented in Table 5.

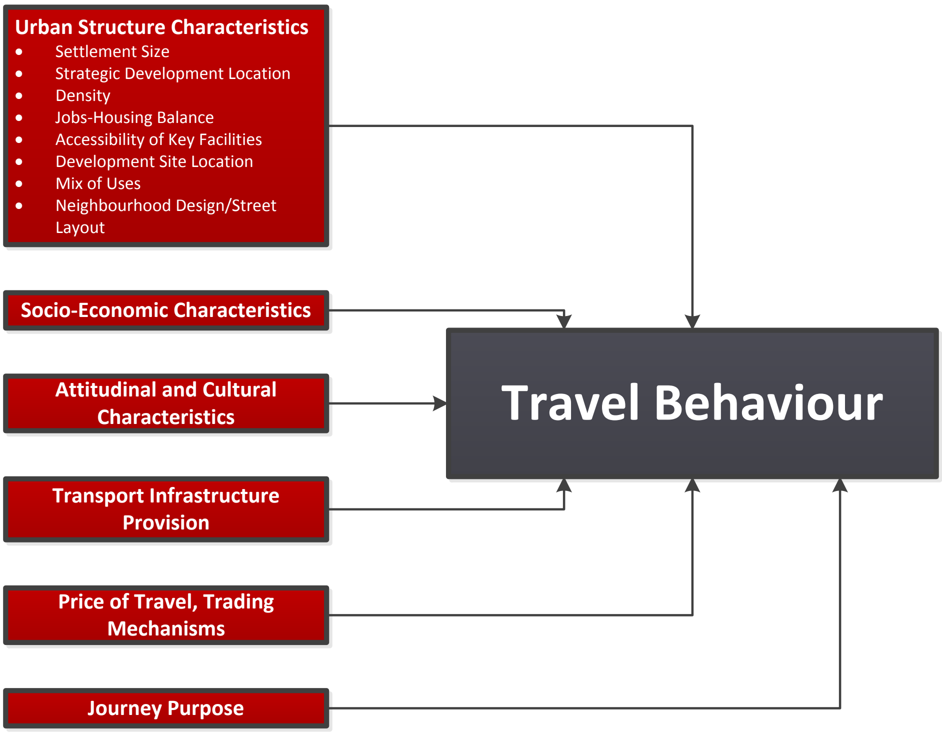


Figure 10: Factors Influencing Travel Behaviour (Hickman, Seaborn, Headicar, & Banister, 2010)

Table 5: Themes of Spatial-Transport Integration

Theme	Meaning
Settlement Size	The total population or number of dwellings within a contiguous built-up area
Strategic Development Location	The selection of areas for major new development between regions and sub-regions, including the spatial distribution of housing and employment within growth areas and between growth points and other urban centres
Strategic Transport Network	Transport infrastructure that support medium and long-distance travel, between towns and cities or along major corridors in urban areas
Density	The intensity of use of land by different uses
Jobs-Housing Balance	The relationship of employment opportunities and workforce population within a geographic area (in ratio jobs per worker)
Accessibility to key facilities	The ease of reaching destinations or activities.
Development site location	The selection of sites for new housing or other developments
Mixed use	The degree to which different land uses are contained within a geographic area, at building, street or neighbourhood level
Neighbourhood design and street layout	The scale, form and function of buildings and open space, and the pattern of local streets (grid, circular etc.)
Travel demand management	Measures aimed at reducing car use and its impacts
Parking	The amount of space planned for storage of cars and other vehicles

What these themes lack, is considering the access and egress sides of transport networks (theme 3). Spatiality does not only influence the dominant public transit service, but also the other transport networks integrated with it. Hence, the influence of spatiality on access and egress modalities has to be involved in the analysis of transport network integration as well. These themes can help to give insight in the relationship of the spatial structure and the transport system. Some of these themes will be used in the construction of a framework for integration assessment in chapter 4. Which themes are used and why are explained in this chapter as well.

3.5.2 Demographics

Apart from spatiality, demographics also influence transport generation and demand, and thus are important to consider in this research. Demographics for this research is explained as the composition of a certain area in terms of households (size, income) and activities at a certain location (work, school, leisure). This is also stressed by Givoni and Banister (2010), who state that the spatial is only one of the underlying reasons for travel. Demand is often driven from socio-economic factors, travel preferences and attitudinal characteristics, see also Figure 10.

KIM (Kennisinstituut voor Mobiliteitsbeleid, 2014) gives four different factors that explain differences in transportation and mobility. The first being the demographic composition of a city or region (in terms of age and people per household), the second being economic structure (in terms of household income, employed citizens, number of students). The research by KIM has shown that in regions with predominantly younger citizens, the use of cars in cities is much lower than in regions comprising of older citizens. This is especially the case for one- or two person households without children. This example shows that the composition of a household in terms of age and number of residents in the household influence the choice of transportation and thus the demand. Also, the socio-economic characteristics of a household, in terms of education and income influence transport demand. Higher educated households are more likely to travel by train and by bike.

Susilo (2010) has research that individual factors are often more important for travel behaviour than spatial factors. Susilo states that these individual factors have been tremendously overlooking in the past. The transport network is often still regarded as a combination of different (sub-)networks, by modality, and which are analysed disregarding the unique individual traveller preferences. Hence, given the influence of individual preferences, as stated above, and the fact that in many researches, these are taken for granted, stresses the importance to incorporate individual preferences in network integration analyses. However, due to the individual nature of these preferences, it is difficult to analyse, model, and predict network integration. Grouping of individual characteristics might prove to be beneficial in this case. This will be explained in more detail in chapter 4.

3.6 Conclusion

This chapter has presented the specific transport system that is researched in this thesis. As explained, the integrated Bus-NMT system consists of different elements (access, access node, bus, egress node, and egress link) and different elements from the system environment (spatial and demographic elements). This chapter predominantly presented findings from literature for characteristics of the different system elements. These characteristics will be assessed and explained in more detail in chapter 4, where the framework is built and explained. This chapter contributes to answering two of the sub questions from chapter 1.

Q4: What elements and can be identified in the integrated bus-NMT network?

In this chapter, first, the definition of as system has been clarified. A system consists of several parts, being the system elements with their attributes (characteristics), the environment of the system with the environmental elements, and the emergence of the system, which is the outcome (or effects) of the system.

For the integrated bus-NMT system, the following elements have been identified:

- The access link;
- The access node;
- The bus link;
- The egress node;
- The egress link;
- Environmental elements
    - Spatial elements
    - Demographic elements

These elements all have different characteristics, which have mutual relationships and influence the effects of the system. These elements help ease the assessment of integration: characteristics of the system can be attributed to these different elements, making it easier to compare different (types of) systems using the framework.

Q5: Which characteristics of elements that could potentially influence transport network integration in bus networks should be considered?

This chapter discussed the emergence and design of the different elements of the integrated transport system. Using literature, characteristics, design considerations and implications for transport network integration have been researched. This leads to the following aspects, per element, that need to be considered when developing the assessment framework:

Access and Egress Links

- The relation between characteristics of the dominant modality and its influence on the 'reach' (the distance) of access and egress modalities.
- The potential for cycling (the share of the modality) as a high flexible access/egress mode, which is complementary to the bus system, but allows for longer distances as opposed to walking.
- The differences between the access and egress side for mode choices (walking/bike).
- The influence of spatial and demographics aspects on access and egress choices in terms of urban density and land-use.
- The SWOTs for access and egress as identified in Table 1.

Bus Links

- The differences in services (and hence values of system characteristics (attributes)) between conventional bus systems and high quality bus systems.
- The different characteristics of the bus service design (e.g. frequency of service, reliability) that can make the bus system more efficient.
- The different design dilemmas of bus network design, which influence integration, for which a trade-off has to be made. These dilemmas are listed in Table 3.
- The characteristics of the bus system that influence ridership. Ridership is an effect of the transport system, and is influenced by integration. Hence, characteristics influencing ridership could alter the (level of) integration of the system.

Access and Egress Nodes

- The reach (or catchment area) of the bus stop, which depends on characteristics of access and egress (e.g. mode choice) and the characteristics of the bus system (e.g. frequency influencing waiting time at the bus stop).

Environmental Elements

- The influence of spatial and demographic characteristics on travel behaviour

These aspects need to be considered in the development of the framework in chapter 4.

4. Framework Development

With the concepts of the integrated transport system and the explanation of this system for bus networks in chapters 2 and 3, the background of this research has been explained. This chapter discusses different prerequisites and considerations that have to be taken into account when designing the assessment framework. These considerations contribute to the design of the framework. Furthermore, the actual framework is presented and discussed, together with the steps of assessment and the affiliated characteristics of elements and the system effects that are taken into account.

4.1 Prerequisites for the Development of the Integration Assessment Framework

Resulting from the literature review of transport integration in chapter 2, three different prerequisites for the framework have already been presented. The framework should be able to capture:

- The influence of network specific characteristics on transport network integration;
- The influence of the integrated transport system on effects;
- The assessment and comparison of different systems in terms of performance characteristics and effects.

These prerequisites are presented in Figure 11 as knowledge gaps. These gaps derive from the lack of knowledge that exists in the transport world today. Section 1.1 already presented the scientific and societal relevance of this research. These considerations are not only important for the legitimacy of this research, but should also be considered in the design of the framework. Figure 11 presents the knowledge gaps existing between different aspects of the transport system, and captures the three prerequisites presented above.

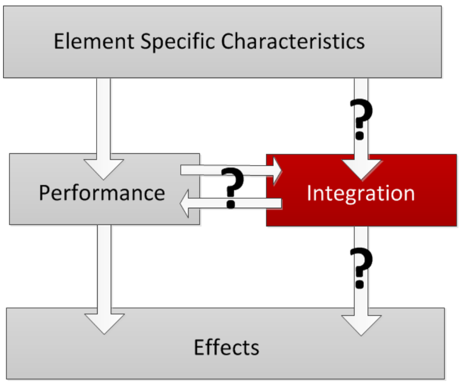


Figure 11: Knowledge Gap in Integration Assessment

When combining the knowledge gaps as presented in Figure 11 with the three mentioned prerequisites derived from chapter 2, and taking into account the different elements and characteristics of the bus system (including its access and egress modalities) as identified in chapter 3, the prerequisites for the framework can be determined.

For the design of the framework, the input, the output and the internal mechanism of the system need to be determined. The ***input*** are the element specific characteristics with their performance. This performance is expressed in a certain value. For instance, the performance of the bus link (see section 3.3) could be expressed in commercial speed (in km/h). This input helps in determining what the influence of these characteristics is on transport network integration. The ***output*** are the effects of the entire system, which are influenced by the composition of the entire transport chain (thus including access, egress, transfer nodes, the bus link and the environment). The output includes measurable effects, for instance the number of passengers. This number will change depending on the composition of the transport chain. Finally the working of the system, or the ***internal mechanism,*** is the actual composition of the system, including elements, their characteristics and the values of these characteristics. This composition differs for every system, and as explained, the composition determines the effects (output), and is influenced by the value of the characteristics (input). Hence, to be able to determine how the composition of the system is influenced by the characteristics and in its turn influences the effects, different systems have to be compared.

4.2 Development of the Assessment Framework

With the three aspects of the integrated transport system (input, output and internal mechanisms) that have been presented in the previous section, the framework can be developed. These three aspects help to include the earlier identified prerequisites in the framework. The three identified prerequisites relate to the framework as follows:

Input

The characteristics of the different elements of the bus system form the input of the framework. These characteristics have a certain value and influence transport network integration. Which characteristics influence the integration and to which extend has to be determined.

Output

The output includes the different effects of the system. These are measurable and are the result of the composition of the system.

Internal mechanism

The internal mechanism is the actual composition of the system, the way these components work together, and influence the effects of the system. The internal mechanism can be determined by comparing different system on their input (performance characteristics) and their output (effects). Hence, the internal mechanism give insight in:

- The way the characteristics influence transport network integration though comparison of systems;
- The way transport network integration influences the effects of the system. This has to be determined by altering the characteristics of a system to determine the influence of these alterations on the system effects.

These three prerequisites are explained in more detail in the next sub-sections.

4.2.1 Input: The Influence of Network Specific Characteristics on Transport Network Integration

As explained in chapter 3, the system of bus services consists of several elements. These elements in turn have certain characteristics, for instance the egress elements have a characteristic ‘distance from bus stop’. The characteristics are measurable. Hence, it is not sufficient to only assess the effects of integration, but insight in the different characteristics that could influence these effects is also needed. Figure 12 presents the relations of integration with the four elements as identified in chapter 3:

- Transport elements
- Transfer elements
- Spatial elements
- Demographic elements

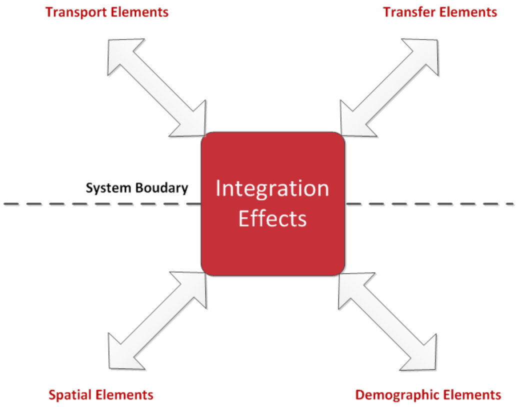


Figure 12: Relations with Integration

Figure 12 also shows the boundary between the system and the environment. Recall Figure 4 from chapter 2, where the system was represented as subsequent links in a chain, influenced by the system environment.

What this figure does not capture, however, is the relationship between spatial and transport characteristics, transport and demographics, and spatiality and demographics. However, these relationships do exist and make the assessment of integration much more complex. Thus, characteristics not only influence the effects (outcomes) of the system, bus also influence one another. A change in one characteristic in the system can in turn change another characteristic, either directly or indirectly. These are the relations between system elements, and between the system and its environment (see chapter 3). The different aspects of the system are linked in such a way that they continuously influence one another. One framework that captures these relationships in a simplified way, is the Land-Use-Transport-Feedback Land-Use-Transport-Feedback Cycle (Wegener, 2004).

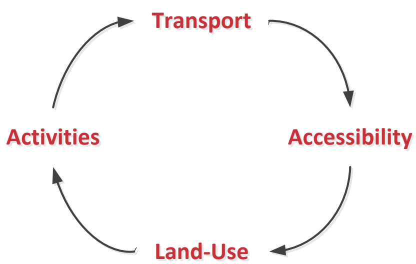


Figure 13: Land-Use-Transport-Feedback Cycle

Figure 13 presents the Land-Use-Transport-Feedback Cycle. What this cycle does is that is shows, in a clear way, the direction of influence in the transport system and its environments, and the way the four aspects influence one another. It shows the interrelationship between transport and spatiality. The different relations between these aspects can be explained as follows (Wegener, 2004):

- ‘The distribution of land uses, such as residential, industrial or commercial, over the urban area determines the locations of human activities, such as living, working, shopping, education or leisure;
- The distribution of human activities in space requires spatial interactions or trips in the transport system to overcome the distance between the locations of activities;
- The distribution of infrastructure in the transport system creates opportunities for spatial interactions and can be measured as accessibility;
- The distribution of accessibility in space co-determines location decisions and so results in changes of the land-use system.’

Land-use relates back to the previously mentioned spatial elements. Activities can be linked to demographics: school-going children travel to school locations, people looking for leisure activities travel to sport facilities, shopping areas and restaurants. The transport part of the cycle, quite obviously, relates to the transport elements of the integrated transport system. The final step of the cycle, accessibility, partially consists of the transfer element. In the transfer node, the different modalities are physically integrated. Physical integration of the networks is part of accessibility: it eases the difficulty to reach a certain destination.

The cycle is a simplification of the real world relationships; characteristics of accessibility also influence activities. Though the land-use transport feedback cycle does give some valuable insight in the relationship between the four different aspects, it is not a framework to assess transport network integration. It does, however, give valuable insight in the direction of relationships, and can thus be used to explain the influence of changes in characteristics on other characteristics and on system effects which explain the internal mechanisms (see 4.1.3) of the system.

4.2.2 Output: The Influence of the Integrated Transport System on System Effects

The previous section explained the influence of characteristics of elements within the system on other elements and other characteristics. The system itself, and with that the different elements and their characteristics, together result in the system effects. Hence, the system as a whole produces effects (or output), which can be measured.

There are three different effects that are the result of the performance of the entire system, that can not be assigned to just one characteristics of the transport system. These include:

- The total travel time;
- The number of passengers;
- The total travel distance;

These effects influence the environment of the system, and can as such be described as 'societal effects', which allows for the assessment of these effects using a societal Cost-Benefit Analysis (CBA). CBA allows for the comparison of different systems (or alternatives of systems) by analysing effects (benefits and costs) of the system performance. These effects will be discussed in more detail in section 4.4, the use of a CBA is explained in chapters 5 and 7.

4.2.3 Internal Mechanism: The Assessment, Comparison and Improvement of Different Systems in terms of Characteristics and Effects

The previous two sections explained the influence of characteristics on integration, and the influence of this integration on the eventual effects of the system. Finally, as explained in chapters 2 and 3, the framework should be able to compare different systems. This includes the comparison of differences between conventional bus lines and BRT lines. There are two ways to comparing systems:

- Comparing the systems on their element specific characteristics gives a chance to review the influence of a specific element on overall integration of a system;
- Comparing the systems in terms of effects gives a chance to review the influence of integration on the actual output of a system, and provides an opportunity to assess the optimisation of integration in terms of system effects.

Hence, the framework should not only assess one specific system, but should provide the opportunity to assess and compare different systems in terms of performance.

4.2.4 Considerations for the Assessment Framework

The three angles of integration assessment that have to be incorporated in the framework have been discussed. Per angle this implies the following:

- Input: The influence of network specific characteristics on transport network integration;
  Implies that the framework should be able to identify and assess different characteristics of the system elements, and should be able to determine the influence of these characteristics on network integration.
- Output: The influence of the integrated transport system on (societal) effects;
  Implies that the framework should be able to determine the effects of a system, and should be able to determine the influence of network integration on these effects.
- Internal Mechanism: The assessment and comparison of different systems in terms of characteristics and effects.
  Implies that the framework should allow for the comparison and improvement of different bus systems.

The next paragraph presents the actual framework.

4.3 Design of the Integrated Transport System Assessment Framework

The previous section addressed the three issues that need to be covered in an assessment framework. To fully grasp these three aspects and cover them in the framework, the framework needs to be able to process the input of the framework (the characteristics with their values) into insight in integration influencing characteristics. The framework should be able to assess the effects of transport network integration on a system. Hence, the framework should be able to assess the system performance, and give insight in integration. Thus, the framework consist of two different parts:

- Bus Network Assessment, which involves the performance assessment of different (types of) bus systems;
- Integration Assessment, which involves the assessment of the manifestation of integration in transport networks and the related integration effects.

From these two parts, two different types of results can be derived from the assessment framework:

- System results, which are the actual values of characteristics and effects of the transport system.
- Integration results, which are the implications for transport network integration derived from the characteristics and the effects. These results directly contribute to the scientific relevance (see chapter 1) of this research, and describe which characteristics influence integration and to what extent.

The first part of the framework (1. Bus Network Assessment) consists of six steps, that together influence and determine the results of part 2 of the framework (2. Integration Assessment). In the first part (1. Bus Network Assessment), two different assessment methods can be distinguished:

- Bus Line Performance Assessment;
  Assessment of the different system elements and their characteristics of different (types of) bus services, including a comparison between different bus lines.
- System Effect Assessment.
  Assessment of the effects of the (optimised) integration of the individual systems, including a comparison between bus lines.

The framework is presented in Figure 14.

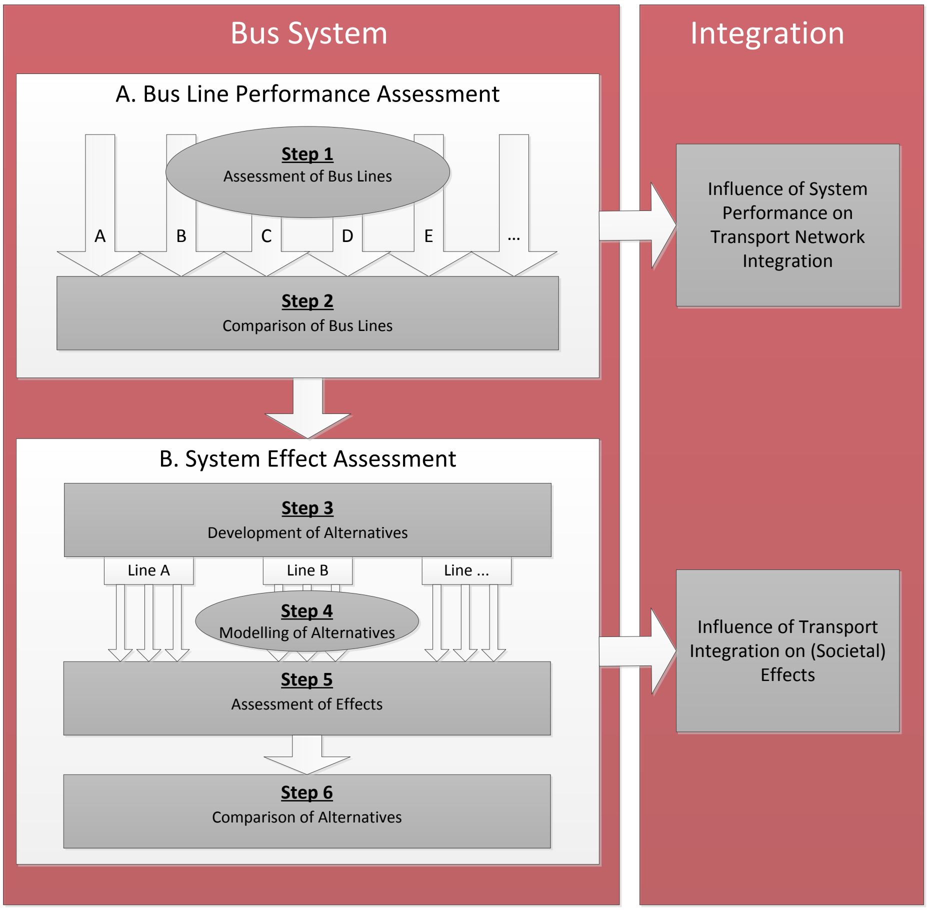


Figure 14: The Assessment Framework

A. Bus Line Performance Assessment

This part covers the first and third prerequisites: the influence of characteristics on integration is determined (prerequisite 1) through the assessment and comparison of characteristics of different bus systems (prerequisite 3). Step 1: assessment of bus lines, involves the assessment of the individual performance of bus systems (all elements). Next, in step 2: comparison of bus lines, the different characteristics of bus lines are compared. This comparison is divided in three parts: the bus type comparison allows to compare conventional lines with high quality lines. The line based comparison allows for the comparison of individual lines, and gives insight in the way characteristics of the system influence integration. The final comparisons, that of individual bus stops, allows for the identification of characteristics at stop level (instead of line level) that influence integration. With this first part of two (A and B) of the assessment framework, insight is gained in the characteristics that influence integration (see Figure 14, Integration results).

B. System Effect Assessment

With the insight gained in part A of which characteristics influence integration, the systems can be altered. Using the insight of part A, alternatives can be developed (step 3). These alternatives are then modelled (step 4) to determine the influence of the alterations on the effects of the system (step 5). Traffic models are a tool that can be used to model the alternatives. These models give insight in the different 'costs (e.g. travel time, distances) affiliated with changes, and help determine the effects of such changes (e.g. in number of passengers). In step 6, the different alternatives are then compared. Methods to compare the alternatives include multi-criteria analysis (MCA) and Cost-Benefit Analysis (CBA). With this final part (part B) of the framework, the second and third prerequisites are covered. The influence of the integrated transport system of effects (prerequisite 2) is determined by comparing the effects of different alternatives (that include alterations) for the same bus system (prerequisite 3).

This framework is a qualitative representation of a quantitative assessment. Each step is explained in the next sections in the qualitative sense of the word in more detail. To add more detail, data requirements, data collection, and the quantitative analysis of these different steps are explained in chapters 5, 6 and 7.

4.4 System Performance Assessment

This section discusses part A. Bus Line Performance Assessment of the integrated transport system assessment framework in more detail.

4.4.1 Step 1: Assessment of System Elements

This step involves the assessment of the different elements of the system. As explained in chapter 3, there are six elements:

- The access link;
- The access node;
- The bus link;
- The egress node;
- The egress link;
- Environmental elements
    - Spatial elements
    - Demographic elements

These elements with their characteristics form the input of the framework. This step of assessment involves assessing the different elements individually and per system (so per individual bus line with affiliated access, egress, transfer and environmental elements). This step also involves analysing the relations between different elements or between different characteristics of one elements. To summarize, this assessment step will give the following results:

- Values of characteristics of elements per system.
- Relations of elements and their characteristics per system.

The next sections explain the different elements and their characteristics that will be assessed in more detail. The choice for these characteristics is based on the literature review of chapters 2 and 3, and takes into account the SWOTs per modality as identified in chapter 3.

4.4.1.1 Environmental Elements

Spatiality

As explained in chapter 3, it is important to include a certain level of spatiality in the assessment of integration due to the influence of these elements on the transport system. Chapter 3 has shown that the structure of the built environment and the activities of a location influence the transport system and vice versa. The built environment influences the penetration rate of (different types of) modalities to a certain area, and influence travel times and distances, depending on the urban density. The urban density is a way to measure the density of the built environment, and indicates the number of addresses in an area. This urban density is called the 'level of urbanisation'.

The activities, as shown in chapter 3, can for instance influence the choice of modality for access and egress. As has been presented in chapter 2, non-home-bound trips (e.g. to work) often have a dominant access modality of cycling and dominant egress modality of walking. Thus, on the home side of the transport chain, which are most likely residential areas, another modality is chosen on the end side of the transport chain. Hence, activities in the catchment area of a bus stop might explain the integration of the bus service with access and egress through that bus stop. Hence, 'activities at a location' have to be taken into account as well.

Summarising, two types of spatiality are taken into account in this research:

- Level of Urbanisation
- Activities at a location

Level of Urbanisation

The spatial level of a region is determined per postal code, and to determine the level of urbanisation, the standards of CBS (Dutch Statistics Bureau) are used (CBS, 2015):

1. Extremely Urbanised: over 2500 addresses per square kilometre;
2. Highly Urbanised: 1500 to 2500 addresses per square kilometre;
3. Moderately Urbanised: 1000 to 1500 addresses per square kilometre;
4. Little Urbanised: 500 to 1000 addresses per square kilometre;
5. Very Little Urbanised: less than 500 addresses per square kilometre.

Using addresses instead of number of households allows for the incorporation of offices and shops in the analysis. A more detailed approach would be to distinguish between the number of households (plus the average number of people per household) in a region, and the number of jobs (as a measure for employment) in the area. However, due to the large amount of needed data needed for this, and the complexity of analysis that exists when determining the attractiveness of an area based on number of households and number of jobs, for this specific research, the level of urbanisation is chosen as a common denominator to incorporate both the number of households, household size and the number of jobs. In future usage of the framework, it could prove to be beneficial to research the influence of a more detailed fragmentation of the spatial element.

Activities

The places and dominance of activities influences the transport system. Areas with predominantly offices will attract a different type of traveller with a different travel motive than areas with a dominance in residential activities. Hence, it is important to include the activities in terms of location. Four types of activities are included in this research:

- Living (residential)
- Work
- Education
- Leisure

As explained in for the level of urbanisation, another way to measure the spatial elements by adding more detail, and instead of describing the dominant activity in a region, is to determine the exact share of activities in a region and relate this to transport network integration. However, as stated before, this asks for more data, and more preparation and assessment time. Analysing the regions for their dominant activity allows for a faster way to assess the relation between spatial elements and integration.

Demographics

Chapter 2 already introduced the influence of demographics on the transport system. People with a lower income will use different modalities and have a different travel pattern than people with a higher income. Demographics adds a whole new layer of complexity to the framework. There are many different demographic characteristics that can influence transport choices. These include (but are not limited to):

- Household Size;
- Household Income;
- Age of the Population.

There is one common denominator that captures the travel choices of travellers that is influenced by these demographic characteristics. This is the travel motive. The age of a population suggests how many school-going children live in a certain region, which can also be captured with the travel motive, where the motive would be 'education'. The income of households is reflected in travel motives through the composition of the household: students (travel motive: education), employed people (travel motive: work), and their leisure patterns (travel motive: leisure or shopping).

Conclusion

When determining the travel motive for the demographic element, this relates to the activity in the destination region. Hence, there is an overlap between the characteristics of the demographic environmental element and the activity characteristics of the spatial element. Thus, it would be an abundance to include both these in the framework. To summarise, the following two environmental characteristics are assessed:

- Level of Urbanisation
- Activities at a location, resulting from the travel motive to a destination.

4.4.1.2 System Elements: Access and Egress

As has been explained in section 3.2 before, there are several aspects that influence the integration of access and egress to the bus network. One of these aspects is the ease with which the bus stop can be reached from the origin. The ease of getting to the bus stop can be presented in the catchment area of the bus stop, indicating the influence area of the bus stop, which is the area in which the bus stop attracts passengers. This catchment area can be expressed in:

- Time (the time it takes to get from the origin to the bus stop, or from the bus stop to the destination);
- Distance.

However, the magnitude of the catchment area heavily depends on the mode choice. Hence, it is important to determine the share of modalities for access and egress. This also allows for the comparison of access and egress stops, as there might be a difference between the catchment areas of this stops caused by modalities available. To Summarise, three characteristics of access and egress links have to be analysed:

- The catchment area in time
- The catchment area in distance
- The mode choice for access and egress.

4.4.1.3 System Elements: Bus Networks

For the assessment of the design of the bus networks the network performance is assessed. Network performance can take many forms, and for this research includes assessment of:

- The Physical Network; which are important to compare different bus services in terms of composition;
- Timetable assessment, which allows for the comparison of services in terms of frequency and reliability;
- Infrastructure
- Capacity
- Speed
- In-vehicle time

Physical Network

- Stop Density, as explained in chapter 3, an increase in stop density might cause a decrease in ridership as a result of the decrease of accessibility of the bus stop.

Timetable assessment

- Reliability (see appendix F, which gives an explanation on how reliability is assessed in this research);

- In space (stop-level)
- In time

- Frequency; which influences the availability of the service, and hence the 'hidden waiting time', which is the time incorporated in the time table that a passengers waits at the origin before heading to the bus stop.
- Service headway.

Infrastructure

- Percentage of dedicated infrastructure along route, as explained in chapter 3, Currie and Delbosc found in their research that the percentage of dedicated infrastructure can explain an increase in ridership.

Capacity of the line

- Depends on the in-vehicle capacity and the maximum number of vehicles which can pass through a fixed point (location) in a given time period.

Speed

- Commercial speed, which includes the operational speed, but also takes into account dwell times at bus stops. For this research, the commercial speed is determined by the length of the line and the time table duration to travel from one end of the line to the other.

In-vehicle time

- The in-vehicle time is determined by several aspects of the bus network. For this research, to be able to compare the performance of different bus lines, it is important to express the in-vehicle time in comparable measures. Thus, the in-vehicle time is presented and analysed as the average time it takes to travel 10 km on the line'.

4.4.1.4 System Elements: Transfer Points

The final steps in the cycle involves the integration of all three pervious aspects. The indicators for transfer points are:

- The waiting time at the bus stop;
- The usage of the bus stop.

The waiting time at the bus stop depends on the frequency of the service (see the previous section) and on the reliability of the service. The usage of the bus stop is derived from the number of times a bus stops at that specific bus stop (to allow boarding or alighting of passengers) in a given time period, as a percentage of the total number of trips. Hence this characteristic describes how many times a bus stop was used in a trip. However, this does not say something about the number of people alighting/boarding, but only illustrates the demand generated from the need to board or align a specific line. The usage of the bus stop can say something about the performance of the stop in terms of demand.

4.4.2 Step 2: Comparison of Bus Lines

The second step of the assessment involves the scoring of the different systems in a scorecard. This scorecard allows for the easy comparison of different bus lines in terms of possible design adaptation that can be made. By comparing the elements and their characteristics for different bus systems, this allows for the identification of possible solutions to improve transport network integration.

4.5 System Effect Assessment

This section discusses part B. System Effect Assessment of the integrated transport system assessment framework in more detail.

4.5.1 Step 3: Development of Alternatives

Resulting from the comparison of system, ways to improve transport network integration by altering characterises of a bus line have been presented. Using these outcomes, the characteristics of selected bus lines can be altered in order to try to optimise integration. Whether or not these alterations really affect the network and the associated integration has to be tested. Thus, different alternatives (or scenarios) are developed, in which characteristics of the service of the transport system are changed.

4.5.2 Step 4: Modelling of Alternatives

After development of alternatives, these alternatives have to be tested. A modelling environment allows for scenario testing. For this research, the alternatives are tested using a traffic model.

4.5.3 Step 5: Assessment of Effects

To be able to determine how transport network integration (the changes in the characteristic of the system) influence the effects (or outcomes) of a system, the different alternatives and their results have to be compared. The 'effects' of the system provide a way to measure these outcomes. Paragraph 4.1 presented three types of assessment effects:

- The total travel time;
- The number of passengers;
- The total travel distance;

The Total Travel Time

The total travel time is an important 'resistance' factor of transport. The lower the total travel time, the lower the resistance. An improved, more seamless trip, would have a lower travel time than the original trip is the different links of the system are integrated better. The total travel time is an expression of the sum of:

- Access time;
- Waiting time;
- In-vehicle time;
- Egress time
- Hidden waiting time (the waiting time 'hidden' in the timetable; which makes travellers having to wait at the origin of the trip before departure).

These separate times are influenced by the characteristics of the elements. For instance, the stop density determines both the in-vehicle time (lower stop density generally indicates a higher commercial speed and thus a shorter in-vehicle time), as well as the access time (lower stop density increases the access time when the same access modality is used).

Calculating the total travel time by taking the sum of the individual time components is too simplistic. Travellers might weigh the different components differently. This results in, for instance, one minute in-vehicle time being valued less than one minute access time. As this research does not calculate the valuation of the different travel time components, the weight of a different research is used to valuate the individual components of time. Abrantes and Wardman (2011) have considered multiple studies in the UK to determine the valuation of time. They have calculated different multipliers to valuate the different time components separately. Table 6 presents the multipliers for the attributes relevant to this study. These multipliers are determined with respect to the in-vehicle time, meaning a multiplier of 1 has the same value of time as the in-vehicle time component. The mean multiplier value from the research is used in this table.

Table 6: Attribute Multipliers

Attribute	Multiplier (μ)
Walk	1.65
Wait	1.70

Hence, the valued time component (VTC) can be determined by:

$$VTC = \mu T_x$$

$$\begin{aligned}
&Where\\
&VTC = Valued\ Time\ Component\\
&\mu = multiplier\\
&T_x = travel\ time\ of\ element\ x
\end{aligned}$$

The total travel time would then be:

$$TT_{y,m} = \mu_a T_a + \mu_{wt} T_{wt} + T_{iv} + \mu_e T_e + T_h$$

$$\begin{aligned}
&Where\\
&TT_{y,am,em} = total\ travel\ time\ of\ bus\ line\ y\ with\ modalities\ am\ and\ em\\
&\mu = mutiplier\ per\ link\ type\\
&T = travel\ time\ per\ link\ type\\
&a = access\\
&wt = waiting\ time\\
&iv = in - vehicle\\
&e = egress\\
&h = hidden\ waiting\ time
\end{aligned}$$

There is no multiplier factor for cycling. For this research, the multiplier for cycling is assumed to be the same as for walking. Transfer time, including a transfer penalty (Van Oort N. , 2011), is not included in this equations, as this research does not consider the transfer between different public transport modalities. When the trip consists of multiple transfers (thus not only between access and the bus system and the bus system and egress), the transfer time and the transfer penalty should be taken into account.

The value of time can be expressed in monetary standards, which is beneficial for the construction of the Cost-Benefit Analysis (chapter 7). If people would only consider travel time as a factor in determining their travel pattern, the lowest resistance would be experienced in the fastest trip. However, trip components are valued differently, as explained. This is the Value of Time (VOT), which is *'the amount of money consumers [..] are willing to pay to save a certain amount of travel time'* (Annema, 2009). The VOT has to be considered when assessing the effects of integration. The VOT gives a chance to consider monetised travel time savings in an analysis (when alternatives of design are compared). This is called the Value of Travel Time Savings (VITS) and can be calculated with the following equation:

$$VITS = \rho(\Delta TT)$$

$$\begin{aligned}
&Where\\
&VITS = value\ of\ travel\ time\ savings\\
&\rho = value\ of\ time\ (constant)\\
&\Delta TT = difference\ in\ travel\ time\ between\ alternatives
\end{aligned}$$

The Total Number of Passengers

When considering the number of passengers under the same environmental (spatial and demographic) circumstances, changes the total number of passengers using a certain bus line are the result of changes in characteristics (parameters) of the system elements. When more passengers under the same environment use a bus system, this suggests that the travel resistance (see chapter 3) has decreased. Hence, the total number of passengers is expected to increase with a better integrated system, since the resistance has declined.

The Total Travel Distance

The total travel distance has also been mentioned as an effect. This distance will not be measured for the complete trip from origin to destination. The total travel distance, is not taken into account in the remainder of this research. The travel time already gives an idea of the possible gains for travellers as the result of increased integration. The total travel distance is a factor that is influenced by the total time budget and might change in the future as the result of better integration. This can be expected when people can travel further distances within the same amount of time, thus could result in people deciding to live at a large distance from the activity (e.g. work). As this is a long-term effect of changes in the transport system, this effect is not assessed in further detail.

4.5.4 Step 6: Comparison of Alternatives

As was the case in step 2 of the framework for individual lines, the different system alternatives have to be compared as well. This comparison is not based on a scorecard, but involves a comparison through societal Cost-Benefit Analysis (CBA). With a CBA the monetised costs and benefits of an alternative can be compared over a longer period of time. Hence, this final step generates the output of the framework: an advice for the adaption of the system based on system characteristics that positively influences the societal cost/benefit ratio.

4.6 Conclusion

The previous chapter discussed issues that needed to be clarified to be able to develop a framework for the assessment of integration. This chapter discussed the considerations that need to be taken into account for the development of this framework, resulting from the conclusions of chapters 2 and 3, and presented the framework that was developed that includes these considerations. In this chapter, two sub-questions of the research have been answered. The framework is a qualitative assessment method that is able to quantitatively assess integration in the bus system.

Q6: Which considerations need to be taken into account for the development of the assessment framework?

The first section of this chapter discussed the considerations that need to be taken into account for the development of the framework. From the previous two chapters, three different angles have been identified, and they have been discussed in more detail in section 4.1. This has led to three distinguishable aspects that have to be captured in the framework:

- *The influence of network specific characteristics on transport network integration;*
  Implies that the framework should be able to identify and assess different characteristics of the system elements, and should be able to determine the influence of these characteristics on network integration.
- *The influence of the integrated transport system on (societal) effects;*
  Implies that the framework should be able to determine the effects of a system, and should be able to determine the influence of network integration on these effects.
- *The assessment and comparison of different systems in terms of characteristics and effects.*
  Implies that the framework should allow for the comparison and improvement of different bus systems.

Q7: How can de different elements of the transport system, including their specific characteristics, be captured in one assessment framework?

The considerations for the framework have been presented. To be able to incorporate these considerations in the framework, the distinction has to be made in two types of assessment: assessment of the bus networks, and assessment of integration. These two types of assessment are can not be considered individually, as the assessment of the bus networks influences the assessment of integration. The assessment of integration is the result of a comparison of different bus systems (bus lines) in the first assessment type. For the assessment of the bus lines, two steps are important, being the assessment of the performance of the bus lines, and the assessment of the effects of the performance. To summarize, the framework consists of the following aspects:

Bus Network Assessment, which involves the assessment of different (types of) bus systems;

- Bus Line Performance Assessment;
  Assessment of the different system elements and their characteristics of different (types of) bus services, including a comparison between different bus lines.
- System Effect Assessment.
  Assessment of the effects of the (optimised) integration of the individual systems, including a comparison between bus lines.
- Integration Assessment, which involves the assessment of the manifestation of integration in transport networks and the related integration effects.

The framework is presented in Figure 14.

Q8: Which characteristics of the elements of the transport system are assessed with the framework?

In the first part of the framework (A. Bus Line Performance Assessment), the characteristics of system elements need to be assessed. Section 4.4 presented the different elements and their characteristics that are assessed using the framework. Table 7 presents the different characteristics per element.

Table 7: Characteristics to be Assessed with the Framework

Environmental Elements	• Level of Urbanisation	• Activities around a bus stop
Access and Egress Elements	• The catchment area in time • The catchment area in distance	• The mode choice for access and egress
Bus Network Element	• Stop Density • Reliability of the service • Commercial speed • In-vehicle time	• Frequency of the service • Percentage of dedicated infrastructure
Transfer Elements	• The waiting time at the bus stop	• The usage of the bus stop

5. Case Study: Introduction and Setup

The framework developed in chapter 4 is tested by applying it to a case study. This case study is carried out for the public transit concession area Amstelland-Meerlanden, which is a region of the concession authority Stadsregio Amsterdam. This case study provides a good opportunity to analyse and illustrate transport network integration using the developed framework. This chapter starts with a brief introduction of Stadsregio Amsterdam and its offered public transport bus services, followed by a more detailed introduction of the concession area Amstelland-Meerlanden. Next, the different bus systems operating in this concession area are discussed and classified. The chapter finishes with presenting the specific methodology for this case study based on the framework, and presents an overview of the data needed to assess the different bus lines.

5.1 Introduction to Stadsregio Amsterdam

Stadsregio Amsterdam (City Region of Amsterdam) is a collaboration between sixteen municipalities in the province of North-Holland, the Netherlands. Stadsregio Amsterdam is responsible for, amongst others, the operation of the urban and regional transportation (Stadsregio Amsterdam, 2014), and is as such the commissioning authority for public transport in the region. Stadsregio Amsterdam is responsible for public transport in its catchment area, which comprises of sixteen municipalities as depicted in Table 8 and Figure 15, and four concession areas presented in Table 9.

Table 8: Stadsregio Amsterdam Municipalities

Aalsmeer	Amstelveen	Amsterdam	Beemster
Diemen	Edam-Volendam	Haarlemmermeer	Landsmeer
Oostzaan	Ouder-Amstel	Purmerend	Uithoorn
Waterland	Wormerland	Zaanstad	Zeevang

Table 9: Stadsregio Amsterdam Concession Areas

Amstelland-Meerlanden
Amsterdam
Waterland
Zaanstreek

Figure 15: Catchment Area of Stadsregio Amsterdam (EMTA, 2012)

The catchment area of Stadsregio Amsterdam keeps on growing, in number of residents, workplaces and number of trips in the region. With a share of 43% of travellers from the Amsterdam region travelling to Amsterdam by public transport (Stadsregio Amsterdam, 2013), and with an expected growth of 20% in public transport trips until 2025, there is a call for smart solutions to facilitate the growing number of trips in the region. As such, Stadsregio Amsterdam has expressed the goal to facilitate more travellers in its network with a higher quality against lower costs, using targeted investments. The goal can be reached by investing in shortening travel times and increasing reliability. Four trends motivate these targeted investments, being:

- Already completed infrastructure projects in the region, which allow for use by public transport services;
- The wish to better spread the traffic flows to the city of Amsterdam over the different transport nodes surrounding the city;
- The continuing development of the city and region;
- The expected cuts in governmental funding.

These trends and goal of Stadsregio Amsterdam are closely related to the trends as described in section 1.1. Hence, analysing the public transport network of Stadsregio Amsterdam proves to be a good case study to analyse and assess the effects of better use of existing transport facilities through improvement of integration. The tendency of Stadsregio Amsterdam is to not reach this goal by making cuts in public transport facilities and networks, but by optimising the use of existing facilities, networks and services, and hence improving the quality, reliability and travel times over the entire catchment area. Public transport networks have to be able to facilitate the growth in demand from the region to the economic heart of Amsterdam (Stadsregio Amsterdam, Schiphol Group, Gemeente Amsterdam, & Strategy Development Partners, 2012). These distances are too large to be covered entirely by bike or by foot, and therefore integration with public transport networks is of crucial importance.

From the multi-modal and interdisciplinary approach of Stadsregio Amsterdam, where not only public transport networks are of importance, but focus also lies on other modalities, this case study is formed. Aim of Stadsregio is to increase the combined share of public transport and bicycle trips in urban areas from 62% to 70% during rush hour traffic, and from 40% to 50% in regional areas (Stadsregio Amsterdam, 2014a). By assessing the performance and affiliated integration of different bus types (conventional and high quality) and their NMT access and egress modalities in one of the concession areas of Stadsregio Amsterdam, and by combining the insight from this analysis with the characteristics of the networks as derived from literature, this case study contributes to the understanding of the influence of integrated public transport and NMT-networks on possible traveller gains, and aims to contribute to a share increase for public transport and cycle trips during rush hour.

5.2 Amstelland-Meerlanden

Although this research aims to give insight into network integration from a generic perspective, a case study is used to help analyse and illustrate the effects of integration. For this research, one concession area of Stadsregio Amsterdam is chosen. This allows for a more detailed analyses (as opposed to analysing the entire network which involves multiple public transport operators).

Amstelland-Meerlanden is a concession area with different spatial levels (rural to urban levels) and a large network of both R-Net and conventional bus lines (Comfortnet). For the case study, this research focusses on the spatial catchment area of Stadsregio Amsterdam, as it was on the 5th of February 2015. This research is restricted to the concession area of Amstelland-Meerlanden (Figure 16), and the effects of network upgrading (from conventional to BRT) and network integration (bus and NMT) in this area. The concession area including bus lines and routes can be found in appendix A.

Amstelland-Meerlanden consists of six municipalities Figure 16. However, bus lines within this concession area of Amstelland-Meerlanden cross boarders, specifically to the municipalities of Haarlem and Amsterdam. Appendix A shows the different bus lines and their routes in the concession area. Amstelland-Meerlanden offers 43 Comfortnet bus lines and 6 R-Net bus lines.

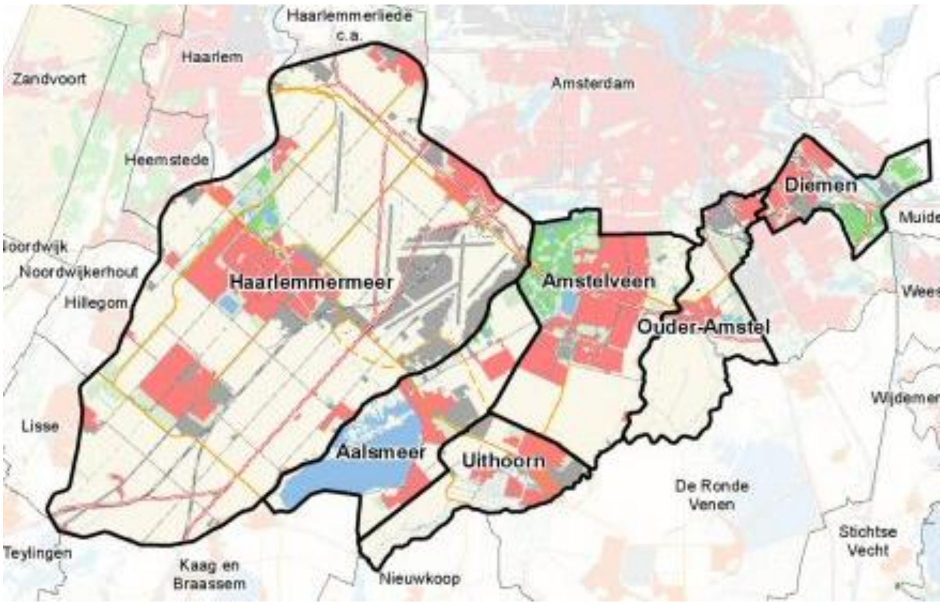


Figure 16: Concession area Amstelland-Meerlanden (Provincie Noord-Holland, 2015)

5.3 Classification of the Bus Systems

Stadsregio Amsterdam currently provides three different types of bus services in its catchment area (Stadsregio Amsterdam, 2013):

- Comfortnet: conventional bus lines, which are feeder lines to other, hierarchically higher, modes of transportation. There are two types of Comfortnet services in Amstelland-Meerlanden:
  - 'Green' (the colour of the operator) lines, which are the lines in the region
  - Ster-net lines, which are the lines that connect the region to Schiphol Airport.
- Plusnet: high quality bus services in the city of Amsterdam;
- R-Net: high quality, high speeds bus services in the region around Amsterdam, connecting different cities, towns and villages in Amsterdam region, and connecting these areas with the city of Amsterdam.

5.3.1 Types of Services in Amstelland-Meerlanden

R-Net and Plusnet are former conventional bus lines that have been upgraded to increase reliability and decrease travel times. Plusnet predominantly focusses on serving the city of Amsterdam, and therefore serves one type of spatiality (the urban region). R-Net is the high quality bus service that serves several types of spatiality, from regional, rural areas to high urbanised regions like Amsterdam and Haarlem. Hence, analysing the differences between R-Net and Comfortnet (the conventional bus network) provides an opportunity to not only analyse the differences of the bus networks, but gives an opportunity to take the spatial level of the service area into account.

Zuidgeest et al. (2009) have identified two types of public transport networks (based on Van Nes (2002)), being connecting networks and access networks:

- R-Net - connecting network: Links busy points of origin and destination, where the stops for connecting transport are located at spots with a high demand for travel;
- Comfortnet – Access network: penetrates deep in areas, zones and city centres, and comprises of traditional bus services with small stop densities.

R-Net is a high frequent, high speed, high quality public transport bus service (Dutch: Hoogwaardig Openbaar Vervoer, HOV) in the region of Amsterdam, and can be identified as Bus Rapid Transit. One of the main goals of the R-Net service is to create an integrated multi-modal transport network, where R-Net connects to other modalities like the train, the car and the bicycle (Stadsregio Amsterdam, 2010).

R-Net provides a possibility to optimise existing facilities, by upgrading existing (conventional) bus lines into R-Net lines (Dutch: Ver-R-Netten), and by upgrading infrastructure to dedicated bus lanes and implementing signalised intersections. The implementation of R-Net has resulted in a growth in the number of travellers (Stadsregio Amsterdam, 2013). Although Stadsregio Amsterdam has ideas and implications on the reasons behind this growth, a more detailed research into the exact consequences of upgrading conventional bus lines into R-Net lines is desired. As such, it is important to gain insight in the effects of changing conventional public transport lines under the commission of Stadsregio Amsterdam into R-Net lines, and to investigate how this influences the goal of Stadsregio Amsterdam to provide the travellers with more reliable, more frequent trips with shorter travel times.

5.3.2 Lines to be Assessed

In the concession area of Amstelland-Meerlanden, 43 Comfortnet bus lines and 5 R-Net bus lines operate. For this research, not all bus lines will be assessed. A choice has to be made which bus lines will be research for the purpose of this study.

Since this research focusses on integration of bus systems with NMT, and tries give insight in the differences between regular bus lines and R-Net, it is important to observe different lines from both types. Furthermore, purpose of this research is to not only focus on integration of the two transport systems, but to also take into account environmental characteristics like spatiality and demographics.

The number of R-Net lines is limited, and therefore the choice has been made to analyse all the R-Net bus lines that serve in the concession area. To be able to analyse the individual lines of the concession area in detail, the choice has been made to analyse the same number of Comfortnet lines, thus 5. In able to incorporate as much environmental and transport network specific characteristics, the list of 43 different Comfortnet bus lines had to be narrowed down to just 5 lines. Appendix A includes a list with all Comfortnet lines.

The Comfortnet lines that serve a too specific type of passengers (school busses, 'buurtbus'), or at a too specific time (night busses, rush hour busses) are excluded first, as these busses will not give insight into the full variety of passengers and bus routes. That leaves a total of 26 bus lines. The next steps involve ensuring different types of spatiality (see 3.4), different uses of space (mainly residential/work/leisure), and frequency of the lines. Furthermore, the routes of the Comfortnet lines have been compared with those of R-Net, to be able to also analyse the differences of the two busses when the routes traverse the same areas. These steps result in the following lines that will be assessed in this research:

Table 10: Bus lines to be researched

Comfortnet	From-To	**R-Net**	From-To
145	Amsterdam Centre – Hoofddorp	300	Amsterdam South-East – Haarlem
146	Amsterdam South-East – Uithoorn	310	Amsterdam South – Nieuw-Vennep
162	Hoofddorp – Lisse	340	Haarlem – Uithoorn
172	Amsterdam Central – Kudelstaart	346	Haarlem – Amsterdam Zuid
187	Schiphol North – Amstelveen	356	Haarlem – Amsterdam Zuid-Oost

These bus lines represent the different bus links (see chapter 3). For these bus lines, the entire system is assessed. This system includes the access and egress links, the bus link itself, transfer points and environmental elements.

5.4 Methodology

The framework for assessment of transport network integration has been presented in chapter 4. For the case study, the entire process of assessment, from data collection to conclusion, involves 5 different steps:

1. Data gathering and processing
2. Assessment of System Performance
   - Assessment of System Elements
   - Comparison of Systems
   - Identifying plications for transport network integration
3. Assessment of System Effects
   - Development of Optimisation Alternatives
   - Modelling of Alternatives
   - Assessment of Effects
   - Comparison of Systems
   - Identifying implications for the effects of transport network integration
4. Evaluation of the framework as an assessment method

5.4.1 Data Requirements and Preparation (Chapter 5)

This step entails gathering the data needed for assessment, and the processing of (raw) input data. Using a traveller survey, the preferences and choices of traveller, in terms of mode choice, access and egress modalities, distances travelled, and travel motives have been researched. This survey hence will give more insight in the effects of network integration from the perspective of the traveller on (1) differences between bus networks, and (2) differences in access and egress, given a certain location. Other data resources apart from the survey are used to gain insight in other characteristics. For instance, the level of urbanisation (see chapter 4) is gathered from the data base of CBS (source). The gathered data will then be prepared to be used in the framework. However, data processing is a gradual process: data has to be prepared not only before using the integration framework, but also during assessment of the consecutive steps.

5.4.2 Assessment of Bus Systems (Chapter 6)

Step 1: Bus Line Performance Assessment

The individual bus lines will be assessed based on the characteristics of elements as identified in section 4.3. This not only gives insight into differences of buses in the same level (connecting or access networks), but also gives a chance to compare the differences between conventional busses and high quality busses in terms of integration with NMT

Step 2: Comparison of Bus Lines

The different bus lines (individual systems) will be compared and relations between characteristics that influence transport network integration are assessed.

5.4.3 Assessment of System Effects (Chapter 7)

This steps involves the same process as presented in chapter 4. And consists of the following steps:

Step 3: Development of Optimisation Alternatives

With the implications of improving integration, derived from the assessment of system characteristics, different alternatives can be generated. The bus lines assessed in the first step are optimised by altering characteristics that have been found (in part A) to influence transport network integration. The generated alternatives than provide a chance to consider and research the effects of changes in the system that should increase integration.

Step 4: Modelling of Alternatives

After the alternatives have been developed, this step involves analysing integration using traffic models. This step will give more insight into the use and possible short comings of traffic models, since network integration is often not incorporated, or not with enough detail. Furthermore, walking and cycling are often presented as one modality in traffic models, making it difficult to assess integration with other modalities. Using the traffic model of Stadsregio Amsterdam (VENOM) the transport network is analysed for integration indicators and effects. The use of network integration in traffic models be modelled using VENOM data in Omnitrans. The validity of using Omnitrans as a modelling tool is discussed in chapter 7.

Step 5: Assessment of Effects

The effects of network integration, following from the model, will be assessed using a scorecard. With this scorecard, the different bus lines can be compared.

Step 6: Comparison of Alternatives

A Cost-Benefit Analysis (CBA) is used to assess the effects of network integration in terms of costs and benefits for society. Focus lies on the societal perspective following from travellers, operators and concession authorities. Hence, using a CBA will illuminate the possible (monetised) societal gains and losses of integrating bus networks and NMT. The results from the modelling of alternatives are used for the development of the CBA. Furthermore, to be able to monetise effects of network integration, Dutch monetisation rules apply. Hence, the CBA for this research is geared towards a transport integration situation in the Netherlands. Nevertheless, the outcomes can provide indications for the societal benefits of network integration in other regions, though aspects like spatiality, welfare and demographics have to be taken into account.

5.4.4 Evaluation of the Framework as an Assessment Method (Chapter 8)

The final step of this research involves determining the usability of the framework for transport network integration assessment. This step has already been mentioned in chapter 1 (methodology).

5.5 Data Requirements

Chapter three presented the framework that will be used for the assessment and comparison of bus lines in Amstelland-Meerlanden. This paragraph explains the data gathered for this research. The zonal data are combined with outcomes of a survey and GOVI data (public transport data), after which the analysis of integration begins (chapter 6). The next section discusses the preparation of the gathered data for analysis.

5.5.1 Zonal Data

Zonal data is needed to assess the environmental elements (spatiality and demographics) of the transport system. To be able to assess these characteristics, the concession region has to be divided in zones for which information can be gathered.

The zones used in this research are the postal codes of the region. The Netherlands has a 6 digit postal code (e.g. 1234 AB) where the four number represent a region within a municipality, and the letters relate to a smaller area within that region, for instance a street. As a lot of data is available for the four digit postal code (4PC), the zone correspond to these 4 digit postal codes.

Per 4PC, the following data has been gathered:

- The level of urbanisation (see section 4.3, source CBS), a 5 point scale that expressed the urban level of the postal code
- The coordinates (longitude and latitude) of the postal codes (Postcode Data, 2015), to be able to determine distances travelled. The coordinates of a postal codes have been determined as the centre of gravity of the postal code with respect to the spread of households (most densely populated sub-region in a postal code area).

5.5.2 Survey

To be able to understand integration, the actual stated choices of passengers have to be known. For this research, a survey has been developed. This survey has been reviewed, improved and carried out by Moventem (source). The actual survey can be found in appendix B.

This survey has been distributed to passengers on the identified 10 bus lines in Amstelland-Meerlanden. Surveyors travelled these 10 bus lines from one end of the line to another, counting alighting passengers and distributing the surveys. The surveys have been distributed on two week-days in April 2015 (Tuesday the 21st and Thursday the 23rd), in three different periods, see Table 11.

Table 11: Survey Times

Time	Type
10.30-15.30	Off-Peak
15.30-19.00	Evening Peak
19.00 +	Evening Off-peak

Distributing the survey both during peak and off-peak hours allows to survey the travel behaviour of a wide range of people, both passengers travelling for work-related purposes (peak) as well as leisure purposes (off-peak).

Table 12 presents the number of responses of the survey.

Table 12: Number of Survey Responses

Line	Boardings	Survey Resonses	Usable Responses	Response (%)
145	119	77	71	60%
146	116	41	40	34%
162	64	36	35	55%
172	318	164	163	51%
187	42	16	16	38%
Total Comfortnet	659	334	325	49%
300	481	122	112	23%
310	149	83	80	54%
340	167	74	68	41%
346	135	99	96	71%
356	287	85	84	29%
Total R-Net	1219	463	440	36%

To be able to ensure that the gather data is valid and a good reflection of the population of Amstelland-Meerlanden, the response rate has to be high enough. Table 13 presents the population size (the number of residents in Amstelland-Meerlanden), the needed sample size, the confidence interval and the margin of error.

Table 13: Statistical Information of the Surveys

	Comfortnet	R-Net
Total Population	260000	260000
Survey Response	334	463
Confidence Interval	95%	95%
Margin of Error	5,40%	4,60%

The margin of error is the range between which answers of the survey will be. To give an example, when there is a 50% change of a certain answer, a margin of error of 5% implies that the answers of the total population will be between 45% and 55%. In statistic research, an acceptable margin of error lies between 4% and 8%. The confidence interval represents how accurate the margin of error is. This means that the confidence interval gives the percentage of the population that would choice an answer that lies within the margin of error.

The preparation of the data gathered with the survey is discussed in the next section in more detail.

5.5.3 GOVI data

GOVI (Public Transport Information without frontiers, Dutch: Grenzeloze Openbaar Vervoer Informatie) is an organisation that provides travel information from busses, trams, metros and ferries. GOVI gathers this information (Big data) for different purposes, for instance to provide live travel information to passengers, but also gathers data for the assessment of the performance of transport systems.

GOVI provides large data files of a bus line that include (amongst others) the targeted route (sequence of stops), targeted arrival and departure times at stops, and the deviation in departure times. These data files can be assessed to gather information needed for integration assessment. The preparation of these files for the purpose of integration assessment is discussed in the next section.

5.5.4 Passenger Data from Qlik

Qlik is a software programme that allows for the storage and analysis of large data files. Stadsregio Amsterdam uses Qlik to store information about the use of the public transport network by passengers. Hence, with the data from Qlik, the number of passengers travelling on a certain line (line ridership) can be determined.

5.6 Data Preparation

The input data as presented in the previous section has to be prepared for assessment. The data is prepared in the following steps:

- Preparation of zonal data
- Preparation of survey data (including combining this step with the previous one)
- Preparation of GOVI data

5.6.1 Preparation of zonal data

The postal codes of Amstelland-Meerlanden have been gathered. Using the database of CBS (source), and (postal code source), the following data is assigned to the different postal codes:

- The level of urbanisation
- The coordinates of the postal codes

Postal codes for which the level of urbanisation was not available have been assigned this level by assessing the level of urbanisation of neighbouring 4PCs.

Furthermore, the bus stops of the assessed lines have been assigned with a postal code, by combining the coordinates of the bus stop (source: Open OV) with the shortest distances to the postal code coordinates. As such, the level of urbanisation for the bus stops has been determined as well. The equations used to determine these distances can be found in appendix C.

5.6.2 Preparation of Survey Data

As can be seen in table XX, the response to the survey was high. In total 797 surveys have been gathered, of which 765 have been marked as 'usable' for this survey. Usable implies that these surveys have been completed and have non-conflicting answers. However, to be able to use the data for interpretation in this research, an extra step has to be taken to prepare the data for assessment.

First, by combining the 4PCs of the origin and destination with their access and egress stops, the access and egress distances have been calculated (see appendix C for the equation). Combining the zonal data and survey data allows to determine the actual length of the links of the trip. In this research, the straight-line distance is used to determine the distances travelled in individual links of the transport chain. Distances via road proved to be too time-consuming for 765 data points. Hence, with an equation determining the distance between coordinates on a sphere, the straight-line travel distances have been determined. This, in combination with the use of 4PC, which is not detailed enough, leads to over and underestimation of distances, as can be seen in appendix D.

To correct these under- and overestimations, a correction factor could be used. However, given the differences in access- and egress modes, and given the fact that it differs tremendously if there is an over- or underestimation, even for the same 4PC, a different, more simplified approach is used. As the radius for access and egress is important, it is important to focus on the maximum distance people are willing to travel. Therefore, it is more important to correct for overestimation. To do so, the percentiles of the distances travelled are assessed. Section XX presents this approach to allow for the comparison of access and egress modalities for different types of bus systems.

Next, the distances travelled by bus have been determined using the same equations and the coordinates of the bus stops. This, like discussed for access and egress, is a simplification of the distance and might be an over- or underestimation, since the straight-line distance between the two points is used rather than the distance over the road.

With this information, the data is assessed. Data has been removed or altered to fit reality. Survey responses that have been removed include those without an origin and/or destination 4PC, and/or those without an origin/destination stop. Alterations of data have only been made when either the origin stop and destination stop had been switched in the survey, or the access and egress modes had been switched. To give an example: it is rather unlikely that someone would travel 40 km by foot, then use the bus for 10 km, and travel by train for 300 meters. It is clear that the modalities have been switched in the survey. Another example is a situation where the stops have been switched: the survey results would in this case have distances for access, bus, and egress links that are about the same in distance, implying someone would have walked 5 km to a stop, took the bus for 5 km and walked 5 km to the destination.

After this step, a total of 681 individual trips (survey responses) are left to be used for the assessment in chapter 6. This slightly reduces the margin of error when the same confidence interval is used. A final remark that should be made when interpreting the outcomes of the survey, is the fact that this survey has been distributed around the evening rush-hour. This has an implication for the assessment and interpretation: where access normally is the home-side trip (home to bus stop) and egress the activity side trip (stop to activity), in this survey, they have been turned around. Hence, when comparing the access and egress outcomes to other researches, it is important to take this into account and to correct for 'switch' this before the comparison of outcomes.

5.6.3 Preparation of GOVI data

The final step of preparation involved the GOVI data. Ten large files containing data for the 10 bus lines in the month March have been assessed. March has been chosen, as this month has a relatively low number of national holidays. As such, March gives a good representation of performance and usage of the transport system when the number of disruptions (due to holidays and for instance maintenance works) is limited. As these files all contain a lot of information, a template has been made in which the data can be inserted. This template generates output important for the assessment of the bus links, including reliability (punctuality determination and punctuality box-plots) and stop usage.

5.7 Conclusion

This chapter discussed the case study. This case study allows for the assessment of the usability of the framework for the assessment of transport network integration. Furthermore, the case study helps concession authority Stadsregio Amsterdam gain insight in the performance of their bus lines in the concession area Amstelland-Meerlanden and gives reference points to the Stadsregio on how to improve integration for these bus lines. In this chapter, one sub-question has been answered that is needed in the preparation of the assessment.

Q9: Which data is needed for the case study?

This chapter discussed the case study area and identified the data needed to assess the integration of the bus lines in this case study area.

In order to assess the integration in this area, the following data input is needed:

- Zonal Data, which relates to environmental specific data (spatiality, demographics) at the level of the four digit (4PC) postal codes.
- Survey data, which gives insight in the travel behaviour and travel choices of passengers
- GOVI data, with which the performance of the bus systems can be assessed.
- Ridership data as collected from the Stadsregio Amsterdam Qlik database.

The data requirements and the preparation of this data for integration assessment in chapter 6 have been discussed in this chapter.

6. Case Study: Performance Assessment

This chapter presents and discusses the first part of the assessment framework (A. Bus System Performance Assessment). The first two steps of the framework (assessment of system elements and comparison of systems) will be discussed. Furthermore, as presented in the framework in chapter 4, this system performance assessment will provide insight in the influence of the performance of the system on transport network integration (Part A: Performance Assessment). The characteristics, responsible for this performance, that influence integration are presented and discussed in sections 6.2 and 6.3.

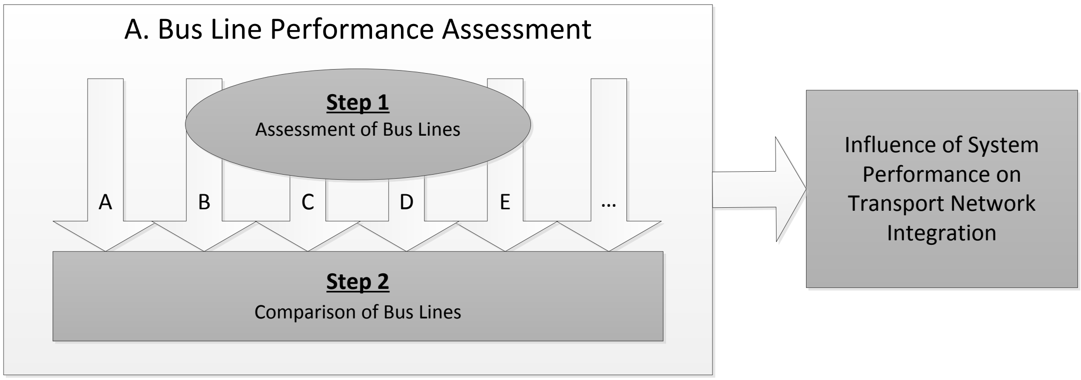


Figure 17: Part A: Performance Assessment

6.1 Assessment of System Elements

Chapter 5 already presented the data requirements for the assessment of system performance, and presented and processed the available data. This chapter starts with an assessment of the general survey outcomes of the 10 assessed bus lines (Table 10). The full outcomes of assessment of the characteristics of the ten bus lines are presented in appendix G. Furthermore, appendix F gives some more insight in how some of these characteristics have been determined. The survey, as introduced in chapters 4 and 5, will first be discussed, followed by the comparison of the two bus service types (Comfortnet and R-Net). This section concludes with a discussion of the assessment of the individual bus lines.

6.1.1 General Survey Outcomes

Appendix E shows the general survey outcomes in full detail. The margin of error and confidence interval of the research have already been discussed in chapter 5. Although the next sub-sections will give more detailed insight in the individual bus lines, a general assessment of survey outcomes gives insights in the travel behaviour of people. From appendix E, three main findings of the survey can be identified:

- ***The frequency of travel;***
  The results show that the majority of people travel 4 to 5 times on the same line, with the same origin and destination (same total trip);
- ***The travel motive;***
  The general survey outcomes show that the vast majority of people travel for work or educational purposes. This supports the earlier finding of the frequency of travel: both work and educational trips are conducted daily to get from home to work or from home to school.
- ***The mode choice for access and egress links.***
  The mode choice for access and egress modalities is of crucial importance for this research, as insight in modal choices for access and egress links helps in the understanding of integration. Hence, mode choice for access and egress need a more elaborate explanation.

The Mode Choice for Access and Egress Links

Chapter 3 already discussed the modal shares for access and egress links in train trips. For train trips, the share of walking is 24% on the access side and 52% on the egress side. For cycling, these shares are 38% (access) and 10% (egress). The modal shares of the bus network (Comfortnet and R-Net combined) are presented in appendix E. To be able to compare bus trips with train trips, the access and egress graphs for bus trips are switched. Remember that due to the nature of the survey (distributed round the evening peak), the access modalities are the ones on the activity sides. In chapter 2 the access modalities are on the home side, hence the pie charts of the assessed bus network from appendix E are switched to allow for comparison. This results in the shares for bus trips as presented in Figure 18 and Figure 19.

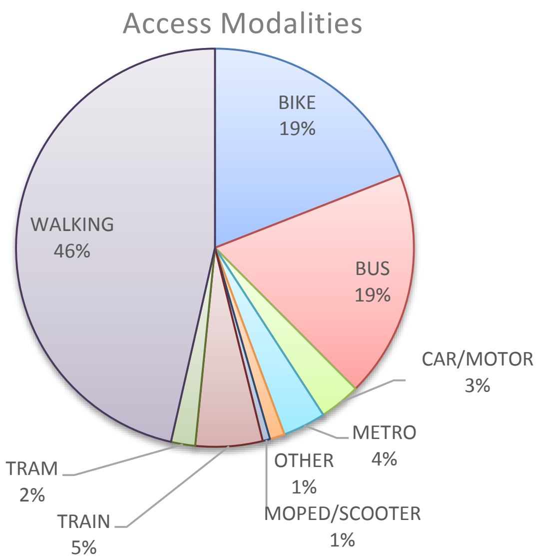


Figure 18: Access Modalities

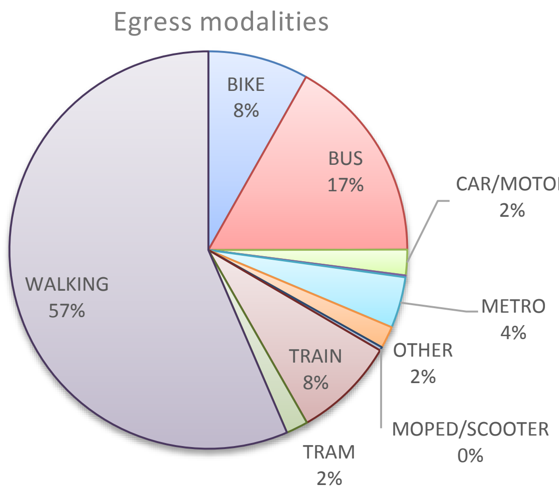


Figure 19: Egress Modalities

From these figures it is clear that, like for train trips, cycling is in important modality in the access and egress links of bus networks. This is especially the case for access trips (activity bound). This can be explained by the fact that, on this side of the trip people often have more modalities at their disposal for the access link and thus have a larger choice. On the activity side (egress), less modalities are available, and walking is by far the most important modality, indicating that distances on the egress side are short. Hence the expectation stated in chapter 2 (high combined walking/cycling shares on the access and high walking chares on the egress side) has proven to be true. Although walking and cycling are often considered as one modality in policy processes (although this is subject to change), this outcomes stresses the importance of approaching these modalities separately. Especially when taking into account that integration factors could be different for different modalities (chapter 3).

One other outcome that should be noted is the use of other bus services as access and egress modalities (19% and 17% respectively). This could indicate that the other (regional) bus services are an important feeder service to faster bus services or last-mile bus services. These figure illustrate the still existing reliability on other services in Amstelland-Meerlanden. This includes other public transport services: the total share of public transport services for access and egress (bus, metro, tram, train) is 30% on the access side and 31% on the egress side of the trip. As discussed in chapter 3, the bicycle could actually be a competitor for bus services in shorter trips. Although not researched in this thesis, this could be interesting to assess in the future. Opportunities might exist on the egress side of the trip (last-mile) if these distances are short (within the cycling threshold), for instance through the supply of cycle-share facilities at important busy bus stops.

6.1.2 Assessment of Individual Bus Lines

Chapter 5 already showed the confidence interval and the margin of error for the R-Net and Comfortnet surveys. When zooming in on the different bus lines, it is likely that the margin of error will increase. This increase implies that the results of the surveys are less likely to be the same in the sample (survey) as in the population. The statistics have been summarized in Table 14.

Table 14: Statistics of Surveys per Bus Line

Bus line	145	146	162	172	187	300	310	340	346	356
Number of Passengers (passengers/week-day)	1950	1350	400	8050	1950	27300	7850	7700	4300	4200
Number of Survey Responses (#)	68	38	31	136	13	104	74	63	81	74
Confidence interal (%)	95	95	95	95	95	95	95	95	95	95
Margin of error (%)	11,68	15,68	16,93	8,33	17.47	9,59	11,34	12.30	10.79	10,30

As can be seen, the margins of error are quite high, indicating that there is a large uncertainty in the survey outcomes. This changes when combining these outcomes in the two groups Comfortnet and R-net. However, for the purpose of this research, it is important to analyse the individual bus lines. Hence, although there are high margins of error, the results are used for assessment. It is recommended that when the experiment is repeated in future research, not only an acceptable margin of error is present in the 'hierarchically-higher' (Comfortnet versus R-Net) comparison, but also within the individual bus lines.

The different characteristics that are assessed for this system are presented and compared the next section.

6.2 Comparison of Systems

The outcomes of the assessment of the individual bus lines (see appendix F) need to be compared. These bus lines are assessed using three different types of comparisons:

1. Bus type comparison, which assesses the results based on differences in R-Net and Comfortnet;
2. Line based comparison, which assesses the result for the 10 different bus lines;
3. Stop based comparison, which gives indications for differences in stop characteristics.

6.2.1 Bus Type Comparison

Given the high error margins of the individual bus lines, a closer look is first taken into the comparison of R-Net with Comfortnet, as these margins or error are acceptable. An acceptable margin of error usually falls between 4% and 8% at a 95% confidence interval level. This is the case for the comparison for R-Net and Comfortnet, see Table 13 in chapter 5.

Modal Shares

First, the modal shares for R-Net and Comfortnet are compared. Figure 18and Figure 19 already presented the overall access and egress shares. Figure 20, Figure 21, Figure 22 and Figure 23 presents these for R-Net and Comfortnet respectively (please note that again the access and egress outcomes of the research have been switched in order to allow comparison with other research. Thus, access is the home-side trip, egress is the activity-side trip).

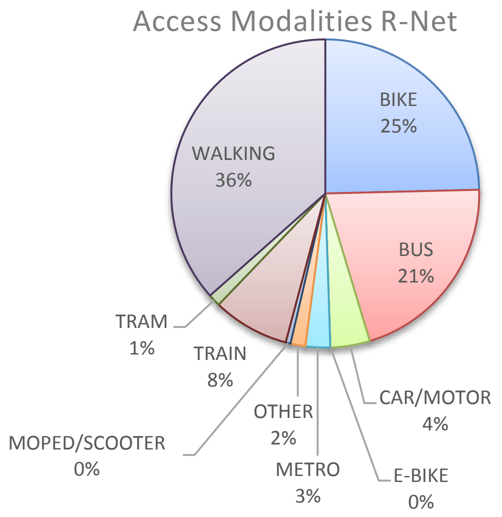


Figure 20: Access Modalities R-Net

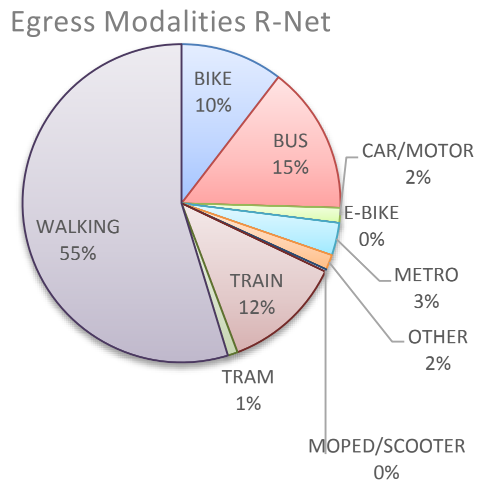


Figure 21: Egress Modalities R-Net

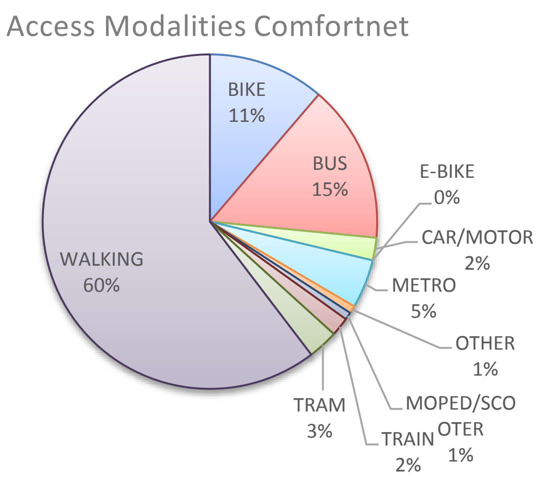


Figure 22: Access Modalities Comfortnet

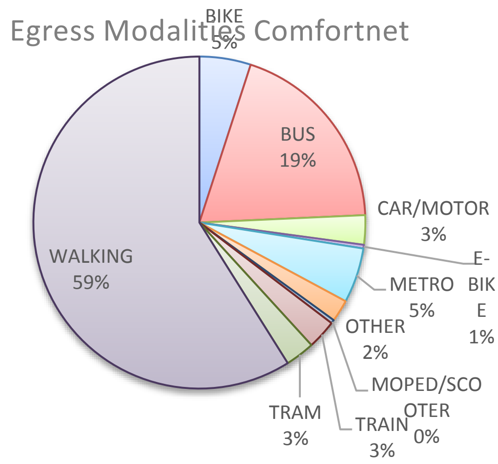


Figure 23: Egress Modalities Comfortnet

When comparing these figures, the bike has a more important position in R-Net trips as compared to Comfortnet trips. One explanation might be that people accept longer access and egress trips due to the (positive) bus trip of R-Net as opposed to Comfortnet. This statement is assessed in more detail in the next sub-section. Another striking observation from these figures is that in Figure 20, for R-Net access, walking has a relatively small share. When comparing this to the train shares discussed in chapter 2, similarities can be seen: the share of walking is much lower on the access side than on the egress side. This points to two explanations: people accept longer distances on the access side (walking has a low share), and on the egress side, people travel short distances, possibly due to the unavailability of other modalities (see chapter 3). Again, these outcomes show potential for supplying bike-share facilities at egress stops, especially for R-Net.

Assessment of the Catchment Area

The catchment areas of R-Net and Comfortnet are assessed for the modalities walking and cycling (see appendix C for the explanation of calculation of distances). This assessment gives a chance to determine differences in accepted access and egress distances for R-Net and Comfortnet. Furthermore, this assessment allows to identify the catchment area for this research for the individual lines to eliminate under- and over estimation (see also section 5.6) It is expected that these distances are larges for R-Net, as R-Net is faster in the dominant trip-side, explaining that people are willing to travel longer in the access and egress sides of the trips when this is beneficial for decreasing the total trip time (recall chapter 3).

Figure 24, Figure 25, Figure 26 and Figure 27 present the distances passengers have travelled for access and egress by bike and by foot, together with the corresponding percentiles. The percentile indicates the value below which the percentage of the survey sample outcomes fall. For instance, in Figure 24 percentile 0,3 indicates that for 30% of the passengers, the travelled distance for access with the bike is 400 meters or less. As with the modalities, the access and egress graphs of this research have been switched to allow for the comparison with research (please note that the titles of the x-axes are thus incorrect).

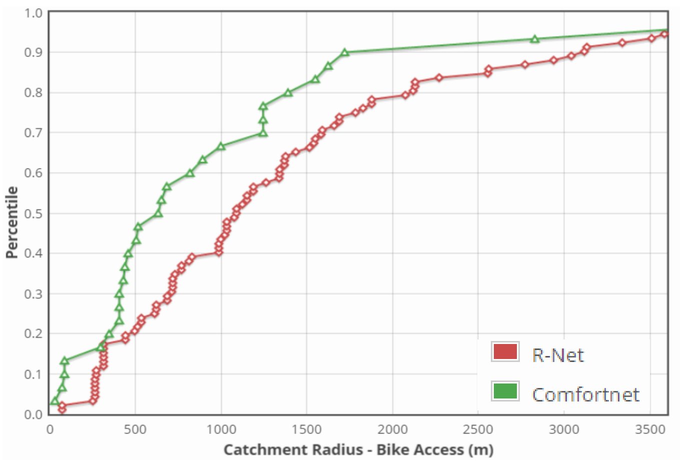


Figure 24: Catchment Radius Bus for the Bike (Access)

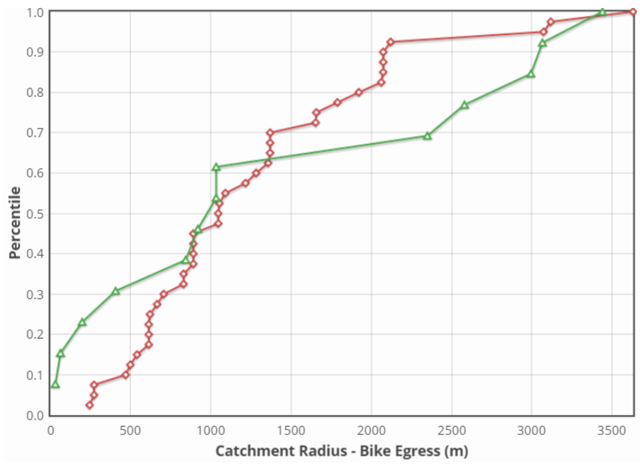


Figure 25: Catchment Radius Bus for the Bike (Egress)

In these figures a larger catchment radius with a lower percentile indicates that a larger share of people are willing to travel larger distances. To give an example: in Figure 24, 40% of Comfortnet users travel up to 500 meters by bike to the bus stop, whereas for R-Net, 40% of the users travel up to 1000 meters by bike. Hence, from Figure 24, it can be concluded that people travel longer distances by bike for R-Net as opposed to Comfortnet. Figure 25 shows something different. There is a clear tipping point between R-Net and Comfortnet. Where for shorter distances, R-Net has relatively more passengers travelling these distances, at around 1300 meters, Comfortnet over takes R-Net in this. This is rather obscure, but can likely be explained by the low number of observations for Comfortnet (14 observations). It is very likely that when the experiment is repeated with more observations, a similar patterns for Figure 24 can be seen, only with shorter distances.

The same assessment can be done for walking and cycling. The results are shown in Figure 26 and Figure 27.

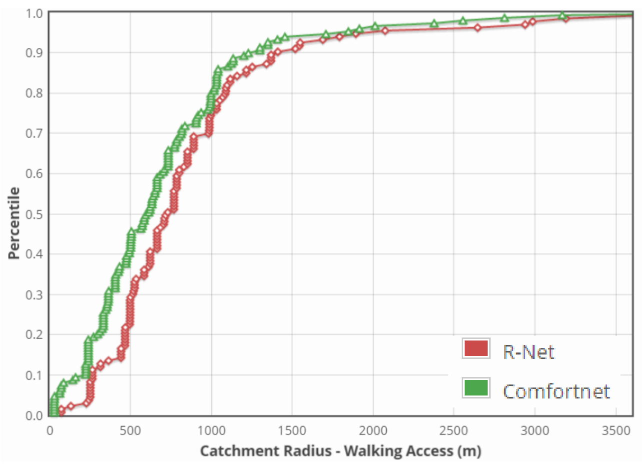


Figure 26: Catchment Radius Bus for the Walking (Access)

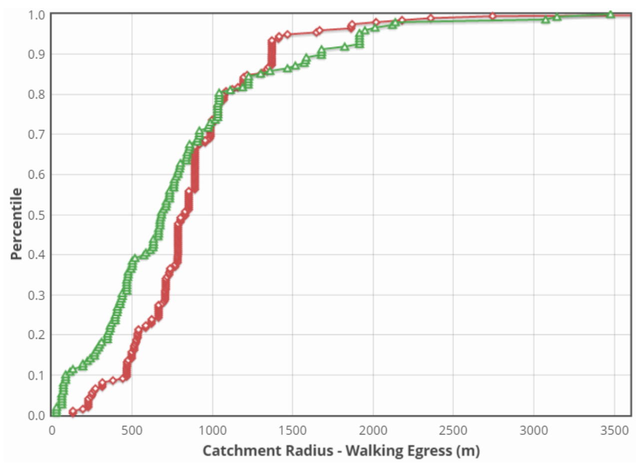


Figure 27: Catchment Radius Bus for the Walking (Egress)

For walking, a similar pattern as for cycling can be seen. However, the difference between the distances is shorter. This can be explained by the nature of the modality, walking is slower, it is thus likely that the threshold for walking distances is lower and less distinctive for Comfortnet and R-Net. In Figure 27, a tipping point for R-Net and Comfortnet can be seen. There is no clear explanation for this. However, as the tipping point occurs for a rather large walking distance, and at a high percentile (this count for only the top 15% of observations), this pattern could be explained based on the reliability of the observations.

As explained in chapter 5, due to the use of 4PC for zones and the use of straight-line distances, over-and underestimations of distances travelled occur. This chapter also explained that it is more important to correct for overestimation (especially when there are more observations). Hence, with these graphs, the upper boundaries used as access and egress distances in the remainder of this research are determined. For walking, the median is chosen. As there are many observations for walking, and the median shows an acceptable walking distance (given the threshold for walking to stops), the median is chosen as the upper boundary for walking. Using these distances cancels out overestimations. For cycling, there are a lot less observations. Hence, it is important for the reliability of outcomes of future assessment to include a large share of observations. As such, for cycling, the upper boundary chosen is the 75th percentile.

6.2.2 Line based comparison

The lines based comparison involves the assessment of the different bus lines on the characteristics as identified in chapter 4 (apart from the spatial and demographic elements, these are discussed in section 6.2.4). The assessment of the individual lines is presented in appendix G, with an explanation of calculations in appendix F. Table 15 presents the scorecard which summarises the outcomes of the assessment.

Not all characteristics of elements mentioned in chapter 4 are included in the scorecard. Since characteristics like spatiality and demographics are determined at the stop level (and not the line level) it does not make sense to include these characteristics in a line-based scorecard. However, relationships between this characteristics are important. Therefore, the next sub-section presents an analysis of these characteristics.

Please note that for this scorecard, the access and egress sides have not been switched to allow for comparison with other research. Hence, the access side in the scorecard is the activity side, whereas the egress side is the home-based side.

Table 15: Line Based Comparison Scorecard

Elements		Characteristic	line 145	line 146	line 162	line 172	line 187	line 300	line 310	line 340	line 346	line 356
Access and Egress	Catchment Area	Access Bike (km) 75th percentile	1,992	1,274	0,000	3,217	2,580	1,957	1,008	1,795	1,655	2,596
		Egress Bike (km) 75th percentile	1,624	2,251	1,245	1,390	0,000	1,659	2,772	2,536	2,025	1,033
		Access Walk (km) median	0,760	0,665	0,586	0,683	0,425	1,033	0,891	0,710	0,830	0,644
		Egress Walk (km) median	0,652	0,579	0,523	0,607	0,393	0,706	0,661	0,526	0,786	0,718
		Average (Cycling and Walking, km)	1,257	1,192	0,785	1,474	0,850	1,339	1,333	1,392	1,324	1,248
	Modalities	Access Cycling	9%	5%	0%	4%	7%	10%	14%	11%	11%	18%
		Egress Cycling	18%	11%	17%	8%	0%	21%	22%	14%	41%	24%
		Access Walking	60%	45%	57%	61%	77%	49%	61%	59%	56%	44%
		Egress Walking	64%	55%	59%	63%	31%	41%	27%	51%	29%	35%
	Travel Time	Access Time Bike (h:mm:ss)	0:05:59	0:03:49	0:00:00	0:09:39	0:07:44	0:05:52	0:03:01	0:05:23	0:04:58	0:07:47
		Egress Time Bike (h:mm:ss)	0:04:52	0:06:45	0:03:44	0:04:10	0:00:00	0:04:59	0:08:19	0:07:36	0:06:04	0:03:06
		Access Time Walk (h:mm:ss)	0:09:07	0:07:59	0:07:02	0:08:12	0:05:06	0:12:24	0:10:42	0:08:31	0:09:58	0:07:44
		Egress Time Walk (h:mm:ss)	0:07:50	0:06:57	0:06:17	0:07:17	0:04:43	0:08:28	0:07:56	0:06:19	0:09:26	0:08:37
		Penalty (mulitplier)	1,65	1,65	1,65	1,65	1,65	1,65	1,65	1,65	1,65	1,65
Bus System	General	Number of stops (#)	43	27	34	55	31	26	19	27	10	14
		Route Length (km)	22,49	16,806	21,885	29,414	26,553	41,679	28,897	26,668	23,506	30,647
	Bus Service	Frequency peak-hour (busses/hour)	4	4	1	6	4	10	10	8	11	8
		Frequency off-peak (busses/hour)	2	2	1	3	4	10	8	8	5	4
		Service headway peak-hour (min)	0:15:00	0:15:00	1:00:00	0:10:00	0:15:00	0:06:00	0:06:00	0:07:30	05:30,0	0:07:30
		Service headway off-peak (min)	0:30:00	0:30:00	1:00:00	0:20:00	0:15:00	0:06:00	0:07:30	0:07:30	0:12:00	0:15:00
	Stop Characteristics	Stop denisty (#stops/km)	1,91	1,44	1,55	1,87	1,17	0,62	0,66	1,01	0,42	0,46
		Average stop distance (km)	0,52	0,7	0,64	0,54	0,86	1,6	1,52	0,99	2,35	2,19
		Stop usage (%)	35%	45%	26%	52%	29%	72%	58%	62%	72%	57%
	Speed	Commercial Speed (km/h)	27	35	26	22	31	37	35	27	40	38
	Infrastructure	Dedicated infrastructure (km)	3,25	11,74	2,255	7,395	3,65	34,6	20,75	9,3	3,2	7,2
		Dedicated infrastructure (% of route length)	15%	62%	10%	25%	14%	83%	72%	35%	14%	23%
	Line Usage	Number of bus trips (# in March)	2312	1408	1060	4502	2398	10179	7136	5690	4528	4920
		Number of passengers (#/week-day)	1950	1350	400	8050	1950	27300	7850	7700	4300	4200
	Capacity	Vehicle Capacity (passengers/hour)	85	85	85	85	85	160	160	160	160	160
		Hourly Capacity (peak -hour)	340	340	85	510	340	1600	1600	1280	1760	1280
	Performance	Deviation from scheduled departure time (h:mm:ss)	0:01:46	0:01:30	0:01:46	0:02:10	0:00:52	0:01:45	0:01:14	0:01:30	0:01:53	0:02:06
		Deviation from allowed departure time (h:mm:ss)	0:00:45	0:00:34	0:00:53	0:01:02	0:00:15	0:00:34	0:00:26	0:00:32	0:01:06	0:00:46
		percentage on time	56%	62%	60%	55%	70%	67%	69%	64%	56%	59%
		Penalty	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7
	Travel Time	In-vehicle time 10km (h:mm:ss)	0:22:00	0:17:00	0:23:00	0:27:00	0:19:00	0:16:00	0:17:00	0:22:00	0:15:00	0:16:00
Transfer points	Waiting Times	Maximum scheduled waiting time (peak) (h:mm:ss)	0:15:00	0:15:00	1:00:00	0:10:00	0:15:00	0:06:00	0:06:00	0:07:30	05:30,0	0:07:30
		Maximum scheduled waiting time (off-peak) (h:mm:ss)	0:30:00	0:30:00	1:00:00	0:20:00	0:15:00	0:06:00	0:07:30	0:07:30	0:12:00	0:15:00

Discussion of Element Specific Characteristics

Table 15 shows the outcomes of the performance assessment of different characteristics of the transport system. The characteristics will be discussed per element briefly.

Access and Egress Links

For the catchment area, the radius is determined according to the standards as presented in section 6.2.1 (median for walking and 75th percentile for cycling). The catchment area is expressed in kilometres. The average radius for each bus line has been determined. Note that this result is rather skewed, since for the walking component, the median is used to determine the distances, whereas for the bike the 75th percentile is used. When comparing the average catchment area, one result that immediately stands out are the catchment radii for R-Net, as the radii of these lines all accumulate around 1300 meters. The Comfortnet lines show a more disperse radius, and ranges between 750 and 1500 meters.

The modal splits of access and egress have already been discussed earlier per bus type. The scorecard shows the modalities per bus line. Most striking percentage is the high share of bicycle usage for line 346, where for the egress side (home-based, as this is the evening peak) the bicycle has a share of 41%. This could be explained by the nature of this line, as line 346 is an express-like service between Haarlem and Amsterdam-South. Hence, this line competes with generally faster modes (e.g. the train), and as such people seem to be willing to travel further (and thus by bike) for this competitive advantage.

With the distances (catchment radius) the access and egress times to and from the bus stop can be calculated. These times have been calculated per modality per link type (access or egress). As can be seen, the access time for walking is in most cases longer than the egress time for waling. Remember that the access and egress directions are reversed, hence, the access in this table is on the activity side. This implies that people accept longer walking distances on the egress side (though access in this research) for walking, possible due to the lack of available travel options. The penalty for access and egress time, already discussed in chapter 4, has been included in the scorecard.

Bus Link

For the bus link, several characteristics of the lines have been assessed. These characteristics are used in the subsequent sub-section to determine if there is a relation between the bus system characteristics and the access and egress links. This relation is expressed in increases or decreases in the catchment area as a result of changes in the bus system.

The different characteristics of the bus link are all quite straight forward. The stop density are, as can be expected, lower for R-Net services, implying that stops are positioned at further distances from one another. As can be seen in the scorecard, the lines with a higher percentage in dedicated infrastructure often have higher commercial speeds. The lack of other road users on these stretches of dedicated infrastructure imply that busses can travel with higher speeds as they are less influenced by other traffic. When looking at the number of passengers using the bus line per week-day, the number for line 162 is strikingly low. This bus service a low-populated area, and the low frequency of the service might suggest people opt for other modalities (e.g. the car) due to the low availability of service. The performance of the bus service describes the reliability of the service, expressed in the punctuality. How this punctuality has been calculated in explained in appendix F.

Transfer Points

For the transfer points, the waiting times have been determined. These waiting times are based on the frequency of the service.

Calculation of the Total Travel Time

With the scorecard, the total travel time can be determined, an indicator for the level of integration of the bus service with NMT access and egress modalitites. Characteristics of the bus link are assessed for their relation with the catchment area. The catchment area is a good indicator for transport network integration. Recall the equations for total travel time in chapter 4:

$$TT_{y,m} = \mu_a T_a + \mu_{wt} T_{wt} + T_{wt} + \mu_e T_e + T_h$$

$$\begin{aligned}
&Where \\
&TT_{y,am,em} = total\ travel\ time\ of\ bus\ line\ y\ with\ modalities\ am\ and\ em \\
&\mu = mutiplier\ per\ link\ type \\
&T = travel\ time\ per\ link\ type \\
&a = access \\
&wt = waiting\ time \\
&iv = in - vehicle \\
&e = egress \\
&h = hidden\ waiting\ time
\end{aligned}$$

The different time components are influenced by characteristics of the transport system. Hence there are not only changes in time components as the result of their characteristics, but also changes between time components as the result of characteristics in other time components. Given the focus on determining the relation between changes in the bus system and the influence on the catchment area (see section 6.2.1), the way characteristics of T_{iv} influence T_a and T_e need to be determined. As explained in chapter 4, the existing transfer time and transfer penalties are not taken into account in this research, as only the transfer between access and the bus system, and between the bus system and egress, are taken into account. There is no transfer between public transit systems in this research.

This research does not try to explain to what extend different characteristics influence these time components. However, chapter 3 already discussed the different characteristics of transport systems that influence the travel time in that link.

T_a and T_e are influenced by the access/egress distance. As discussed in chapter 3, this distance depends on:

- The directness of travel
- The urban density of the area
- Personal characteristics like age and ability.

Furthermore, as discussed, changes in the catchment area are influenced by changes in the bus link, as this is influenced by travel behaviour.

T_{iv} is influenced by the directness of the bus stop, the total distance travelled, but also depends on service characteristics of the bus system. These service characteristics include:

- Dwell times at stops
- Acceleration of the vehicle
- Dedicated infrastructure
- Speed of the vehicle

T_{wt} is influenced by both the frequency of the service, as well as by the reliability of the service.

T_h is influenced by the reliability of the service.

All these different characteristics have been captured in one equation. As has been mentioned, this research tries to assess the way changes in the bus system influence the catchment area, and as such integration. This is done by identifying which characteristics influence the catchment area.

Hence, the influence of T_{iv} on T_a and T_e has to be determined. To allow for a comparison, T_a and T_e only depend on the distance (not on directness and urban density) and on relative changes from T_{iv}.

Apparently, people accept and increase in the access/egress (and with that in T_a), when the benefits of the other components in the equation (T_{wt}, T_{wt}, T_h) due to changes in the bus link (e.g. speed, frequency) outnumber the costs of the extra T_a or T_e.

The total travel time is determined using the values of travel time as presented in the scorecard, the equation for total travel time, and the multiplication factors as presented in Table 16.

Table 16: Attribute Multipliers

Attribute	Multiplier (μ)
μ_a	1.65
μ_e	1.65
μ_{wt}	1.70

This results in the total travel times per combination of modalities as depicted in Table 17. TT indicates the total travel time, a combination of W-B-W indicates an access modality of walking, the bus link, and an egress walking link. C stands for cycling.

Table 17: Total Travel Times per Modal Combination

	line 145	line 146	line 162	line 172	line 187	line 300	line 310	line 340	line 346	line 356
Total Trip Time W-B-W (h:mm:ss)	1:06:59	0:58:10	1:47:21	1:05:20	0:50:52	0:57:58	0:54:54	0:55:25	0:55:28	0:52:32
Total Trip Time W-B-C (h:mm:ss)	1:02:07	0:57:50	1:43:09	1:00:12	0:43:05	0:52:12	0:55:32	0:57:33	0:49:56	0:43:26
Total Trip Time C-B-C (h:mm:ss)	0:56:55	0:50:59	1:31:33	1:02:36	0:47:27	0:41:26	0:42:53	0:52:23	0:41:41	0:43:32
Total Trip Time C-B-W (h:mm:ss)	1:01:48	0:51:18	1:35:44	1:07:44	0:55:14	0:47:12	0:42:15	0:50:14	0:47:14	0:52:38
Average (h:mm:ss)	1:01:57	0:54:34	1:39:27	1:03:58	0:49:10	0:49:42	0:48:53	0:53:54	0:48:35	0:48:02

The total travel time is a determent for the level of integration, as the total travel time is the weighted sum of different components of the transport chain that together determine the efficiency of the trip. Hence, given Table 17, it can be concluded that line 356 is the most integrated line in the network, closely followed by the other R-Net lines.

Assessment of Relations between Characteristics

With regression analysis, it can be determined which changes in the bus link cause an increase in catchment area (and with that an increase in integration). These relations all show how a certain characteristic of one elements (e.g, the bus system) influences the characteristics of the other elements. For policy makers and operators, it is easier to alter bus specific characteristics to allow for an increase in catchment area (if possible) and thus attracting more travellers. Therefore, using regression analysis, the bus factor is the one that can be altered (the independent X-value) and the access/egress element is the one that is changed by that (the dependent Y-value).

At a first glance, there are three characteristics that seem to explain changes in the catchment area:

- The stop density of the bus service;
- The speed of the bus service;
- The frequency of the bus service;

These are all characteristics that differ between conventional lines and high quality lines. High quality bus lines often have higher speeds and frequencies. To be able to reach certain speeds, the stops are positions at further distances from one another. Other characteristics could also explain a growth in the catchment area, which include comfort at the stop and information of arrival times. However, these are directly linked to- or the direct result of the above mentioned characteristics. The percentage of dedicated infrastructure influences the speed of the bus service, as the performance of the bus is less affected by other road users (e.g. congestion), and is as such included in the assessment. The maximum waiting time directly relates to the frequency of the service. Hence, the three mentioned relations are assessed per modality (see appendix H).

These relations are assessed using a regression analysis. Regression analysis can be used to determine if a relation between two characteristics exist. There is an independent characteristic X that influences characteristic Y. When the p-value of this relation is smaller than 0,05, the relation is significant and exists. This means that the differences between a linear line (the relation) and the data points is small enough to accept the existence of the relation. With the regression line equation, the dependent characteristic Y can be predicted using the equation: $Y = ax + b$, where a is the coefficient (or value) for x, the independent characteristics, and b is a constant. The outcomes of the regression analysis can be found in appendix H.

The relations that show a significant value for walking, do not show a significant value for cycling. This could be explained by the small number of observations for cycling links, especially when considering the fact that the individual bus lines are assessed (and not the bus types). For every relations, four modal-link combinations have been assessed:

- Bike Access
- Bike Egress
- Walking Access
- Walking Egress

Stop Density and Catchment area
When plotting the stop density and the catchment area, the regression lines shows a negative relation for three out of four assessed modal-link combinations. However, these relations are not significant, and the changes in stop density can not explain changes in the catchment area.

Service Speed and Catchment area
The plots of the relation of speed and catchment area show a positive relation for three of the modal-link combinations. Only the cycling access (activity based) shows a negative relation, but this can be explained by the small number of observations. The relations are only significant for the walking trips. Again, the insignificance of the cycling trip could be explained by the small number of observations for cycling in general. The importance of a large amount of observations is stipulated by the outcomes of the relation for walking. The walking access (activity based) is significant, whereas the walking egress is not. This could be explained by the number of observations: 380 for access over 307 for egress. Hence, a recommendation for a repetition of the survey, or when surveying a different network, is to ensure more observations are made.

In the next chapter, the access and egress travel times determine the total travel time, where the different time components of the equation differ in accordance with alterations in alternatives. To calculate the change in the catchment area for a change in speed, the regression equations that can be derived from this regression analysis are used. In this research, the relation with the most significant value is used, to correct for errors as a result of the number of observations.

The analysis resulted in the coefficients for the catchment equations as presented in Table 18.

Table 18: Coefficients for Speed and Catchment area

	Coefficient	*P*
Constant	0,269	0,017
Speed	0,011	0,083

Hence, the regression line that explains the relation between the catchment area and the speed can be determined by:

$$Catchment = 0{,}269 + 0{,}011v$$
$$where$$
$$v = speed$$

Service Frequency and Catchment Area

Plotting the relations of service frequency with the catchment area shows a positive relation (an increase in frequency will cause an increase in the catchment area). For this assessment, the peak-hour frequency is used. However, as was the case for the speed, this relation is not significant for cycling trips. The relation is, however, significant for walking trips. Tables XX and XX show the coefficients and p-values for these relations

Table 19: Coefficients for Frequency and Catchment area, Access

Access	*Coefficient*	*P*
Constant	0,482	0,001
Frequency	0,036	0,020

Thus, the equation to determine the catchment area for access trips is:

$$Catchment = 0{,}482 + 0{,}036f$$
$$where$$
$$f = service\ frequency$$

Table 20: Coefficients for Frequency and Catchment area, Egress

Egress	*Coefficient*	*P*
Constant	0,459	0,000
Frequency	0,024	0,030

And the equation for the egress catchment area:

$$Catchment = 0{,}459 + 0{,}023f$$
$$where$$
$$f = service\ frequency$$

Speed and Frequency

As will be explained in chapter 7, alternatives will be developed that involve changes in both the frequency and the speed. To be able to calculate the catchment area for these alternatives, a multiple-regression analysis has to be carried out, where multiple independent X-values are present. This analysis is presented in appendix H. The multiple-regression analysis shows that the coefficients for the different variables (speed and frequency) are not significant (the p-value is too big). As such, the radius of the catchment area can not be determined with both the frequency and the speed.

6.2.3 Stop based comparison

As explained extensively in chapter 3, it is important to consider elements from the environment that influence travel choice and thus influence integration. The elements discussed are spatial elements and demographic elements. As these elements are location bound, it is not possible to consider these elements for the entire line, as a line traverses many postal codes with many different characteristics and values of these elements. Appendix H includes tables per line where the classification of the bus stops is discussed. Due to the amount of surveys, there is no information about all stops. Hence in further research, when trying to assess the spatial elements, it is important to include a thorough stop-based analysis, with a large enough sample size.

The stops are analysed for their catchment area (when information is available) and:

- The spatial level
- The activities (demographics) in the postal code
- The type of bus stop (access or egress)

These are compared for Comfortnet and R-Net. Thus this analysis gives an overview of the average catchment area per spatial level and the average catchment area per activity. Furthermore, it is assessed whether particular stops are more 'access' stops, and which stops are more 'egress' stops. The stops are only assessed for walking modalities, as these have a large enough number of responses.

Assessment of Spatial Levels

Appendix I presents the spatial stop based comparison of bus lines. First, the stops for which data is available have been identified. The list of these stops is presented in appendix I. A regression analysis is conducted to determine if there is a relationship between the level of urbanisation (see chapter 4, which identified 5 different levels) and the catchment area.

Table 21: Catchment radii for Comfortnet compared to the Spatial Levels

Spatial Level	Catchment Radius (km)	Observations (#)
1	0,823	25
2	0,934	6
3	0,667	24
4	0,585	7
5	0,364	1

Table 22: Catchment radii for R-Net compared to the Spatial Levels

Spatial Level	Catchment Radius (km)	Observations (#)
1	0,792	19
2	0,751	11
3	0,973	13
4	1,199	1
5	1,076	7

Table 21 presents the different levels of urbanisation (1 for highly urbanised, 5 for not urbanised) and the corresponding radii for Comfortnet, Table 22 presents these values for R-Net. From these tables, the relation between the spatial level and the catchment radius is not immediately clear. Hence, using a regression analysis, the two relationships (one for Comfortnet and one for R-Net) are visualised. Appendix I shows that both relations have a significant value.

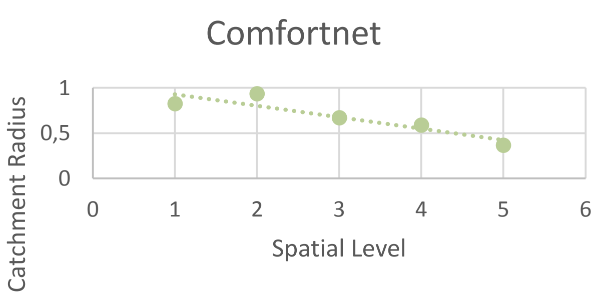


Figure 28: Relation of Catchment radius and Spatial level, Comfortnet

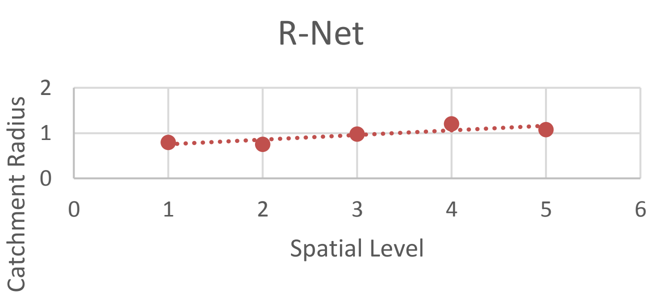


Figure 29: Relation of Catchment radius and Spatial level, R-Net

Figure 28 and Figure 29 visualise the relations of the catchment area with the spatial level. Striking is that for Comfortnet, this relation is negative (the lower the urban density (level 5), the smaller the catchment radius), whereas for R-Net, the relation is positive (a lower spatial level (5) has a larger catchment radius). Although the regression analysis does not give an explanation of why these relations are different for the two bus systems, an educated guess can tell a little bit more. The bus networks of R-Net serve more important destination from the region. Hence, people are more likely to walk further distances in the region (level 3, 4 and 5) if the bus service has advantageous characteristics (speed, frequency). In the city centre, R-Net is not faster than Comfortnet, and thus loses it competitive advantage, making that people walk shorter distances in level 1 and 2 areas. This, however, does not explain the high distances walked for Comfortnet line services in urbanised areas. An explanation can be found in the usage of bus lines in the city centres of the Stadsregio, where regional (city) bus services attract a total share of 97% of all passengers (Stadsregio Amsterdam, 2014a).

Assessment of Activities

The assessment of activities has shown no significant relations. This could be caused by the use of 4PC to assess activities. This more general zonal level (instead of the more detailed 6PC) results in rather large regions that can be assigned as 'residential', while there is a large educational facility that attracts the largest number of passengers. Table 23 and Table 24 present the different activities and their corresponding catchment radii.

Table 23: Catchment Radii and Activities for Comfortnet

Activity	Catchment Radius (km)	Observations (#)
Residential	0,779	32
Work/Education	0,761	12
Leisure/Shopping	0,583	5
Mixed	0,715	13

Table 24: Catchment Radii and Activities for R-Net

Activity	Catchment Radius (km)	Observations (#)
Residential	0,833	19
Work/Education	1,002	15
Leisure/Shopping	-	0
Mixed	0,920	7

Figure 30 presents a visualisation of the catchment radius and the activities, both for Comfortnet as well as for R-Net. This figure again that distances travelled on either the access or the egress side are larger for R-Net services. However, as no significant relation between the catchment area and the activity has been found, no sound conclusions can be drawn from this figure.

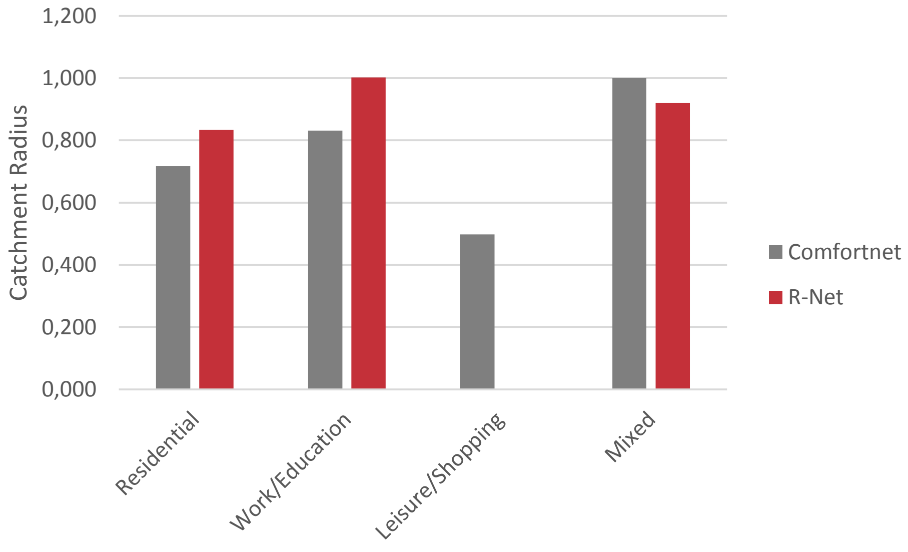


Figure 30: Activities and their corresponding catchment radii

Assessment of Type of Bus stop

For this final analysis, given the limited number over observations, not all stops can be considered to allow a high enough reliability of outcomes. Therefore, the nog all stops are assessed. Assessment is limited to:

- Stops that have more than 5 observations
- Stops that clearly indicate of a stop is either access or egress by only assessing stops with a share of 70% or higher in either one of the stop types.
- Catchment for Walking links
- Only determined for walking (most data, otherwise little knowledge)

This results in a lists of stops as presented in Table 25. The assessment has only been carried out for walking links on the access and egress sides. Note that the access side represents the activity side, whereas the egress side represents the home-based side.

Table 25: Catchment area in relation to the typology of the bus stop

	Access	Egress
CN all stops	0,700	0,550
RN all stops	0,800	0,600
CN	1,043	0,596
RN	0,847	0,823

This table shows that when a stop is an access stop for a Comfortnet line, people walk longer distances when compared to all Comfortnet stops (median). Recall that the access side in this research is the activity based side, thus the side with a smaller choice in last-mile modalities. This could explain the longer (accepted) walking distances, people have no other options available and therefore accept a longer walking distance. For R-Net, there is no real difference between access stops compared to all stops.

Striking is that on the egress side, people travel longer distances by foot for a dominant egress stop than for other stops. An explanation can be found in the fact that R-Net serves important bus stops in both the region as well as in the cities. These important stops are located near work and education facilities, and hence it is likely that people have to travel further on the home side. Apparently, these longer distances are accepted, probably due to the positive characteristics (speed, frequency) of R-Net.

6.3 System Performance and Integration

The pervious sections discussed the assessment and comparison of the different bus lines. By determining the influence of T_{iv} on T_a and T_e, two relations have been identified:

- Speed
- Frequency

These relations showed significant values for walking, both on the access and egress sides. No significant values for relations with cycling access and egress have been found. Another relation that has been found is that of the spatial level (level of urbanisation) and the catchment area of the bus stop. For Comfortnet lines, the catchment area is larger in more urbanised region, whereas for R-Net, the catchment area is larger in more rural areas.

To be able to understand the influence of system characteristics on integration, it is important that this experiment is repeated. This repetition ensures that the relations between speed and catchment area and frequency and catchment area do exist. Other relations that have been assessed but have been found not to be significant could produces significant values when the experiment is repeated with more observations. Furthermore, further research using the assessment method allows for the identification of other characteristics (e.g punctuality of the service) that have not been considered in this experiment.

6.4 Conclusion

This chapter presented the first part of the assessment framework, Bus Line Performance Assessment. This part of the assessment framework consist of two steps: assessment of system elements and comparison of systems. The assessment of system elements can be found in appendices G, H and I.

Q10: Which specific characteristics (e.g. network design) of elements influence network integration?

This chapter discussed the comparison of the different elements for bus lines. By introducing a standardised equation for total travel time (see chapter 4) the strength of integration of a line has been determined. By comparing the integration of these systems, three characteristics of the bus system that could potentially influence the catchment area of access and egress have been identified:

- The stop density of the bus service;
- The speed of the bus service;
- The frequency of the bus service.

The next step in this assessment involved the analysis of these relations, to see if there are any significant relations that could explain transport network integration. Using regression analysis, two characteristics of the bus network have been identified that influence transport network integration for walking:

- The speed of the service
- The frequency of the service

No significant relations have been found for cycling access and egress links.

Furthermore, section 6.2.3 showed that there is a relation between the type of bus stop (access or egress) and the catchment area. For access stops, people travel longer distances by foot (not that this is the activity based side), probably because of the lack of availability of other modalities. On the egress side (home-based), distances for egress stops are shorter than for non-classifiable stops. Section 6.2.3 has also shown that integration is influenced by the spatial level of the area around the bus stop. For R-Net, the catchment area is larger for more rural areas, whereas for Comfortnet, the catchment area is larger in urbanised areas.

To summarise, integration is influenced by:

- The speed of the bus service
- The frequency of the bus service
- The level of urbanisation of the bus stop
- The typology (access or egress) of the bus stop

7. Case Study: Effect Assessment

Chapter 6 described the first of two parts (A. Assessment of Systems) of the assessment framework. The final part (B. Assessment of System Elements) and the final four steps are discussed in this chapter. Figure 31 presents the part of the assessment framework that is discussed in this chapter. With the insights in changes in effects as the result of alterations in the bus system, this chapter also gives insights in the influence of integration on system effects.

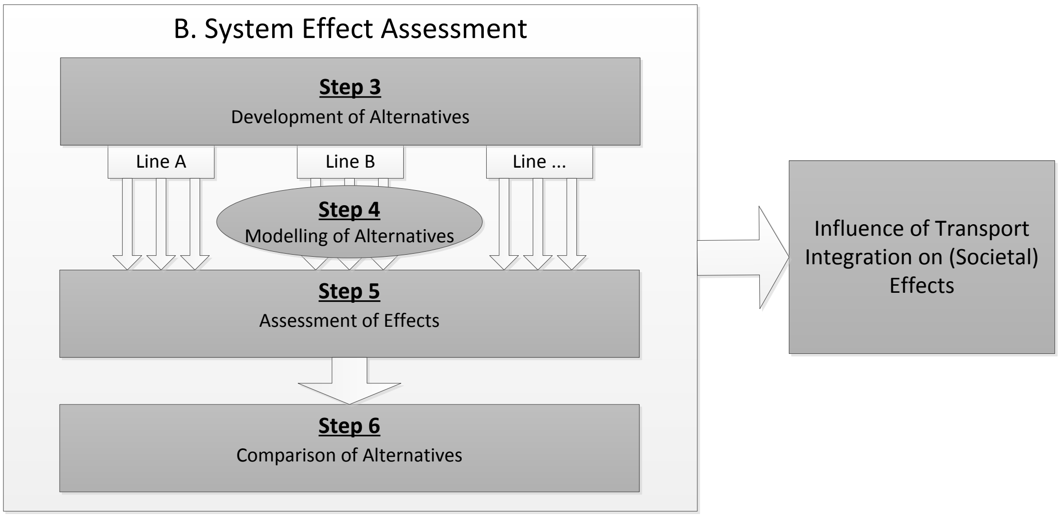


Figure 31: Part B: Effect Assessment

7.1 Development of Optimisation Alternatives

Section 6.2 described how different characteristics of system elements influence transport network integration. With this knowledge, bus lines in Amstelland-Meerlanden can be adapted in such a way that the whole system (bus line) is better integrated with access and egress modalities. This sub-section first describes the bus lines that have been chosen to be assessed in more detail. Next, the integration influencing characteristics are discussed in relation to these two systems. Finally, this results in different alternatives that have been developed per system.

7.1.1 Influencing Characteristics and the Bus Lines

Chapter 6 has shown that there are two relationships that have a significant relation (where $p<0{,}05$) with the catchment area around a bus stop, being the commercial speed (or operational speed), and the frequency of the bus service. This implies that by increasing frequency and/or speed of a service, the catchment area around a bus stop increases. Hence, this indicates that people are prepared to traveller longer distances (by foot, as for cycling no significant relations was found), on the access or egress side when the bus trips is either faster (less in-vehicle travel time) or more frequent (less 'hidden' waiting time), resulting in a better integrated system. Hence, for the development of alternatives, the frequency and the speed have to be addressed.

7.1.2 Bus Lines to be Assessed

Steps 1 and 2 of the assessment framework (part A) assessed ten different bus lines. The final four steps (steps 3 to 6) take a more detailed look at two of these lines. As explained in chapter 1, apart from integration, this research also aims to give insight into the differences in integration for conventional bus services and high quality services. In Amstelland-Meerlanden, both services are present. Hence, this research takes a closer look at two of such lines: Comfortnet, 172, and R-Net 300.

Comfortnet 172 is assessed as this seems to be the most promising of the 5 assessed Comfortnet-lines to be 'ver-R-net' (upgraded to a High Quality Bus System), and the one that is likely to benefit most from an upgrade given the number of passengers that use the service every day.

Bus 300 is assessed as well. This is an R-Net line that has been highly optimised already. With over 80% of the infrastructure consisting of dedicated bus ways or bus lanes, the busses of line 300 can operate at higher speeds due to the dedicated infrastructure and (lack) of congestion caused by road users that would normally share the road. Furthermore, line 300 has a high frequency and links two cities with the highest level of urbanisation (Amsterdam and Haarlem) in the region together. However, there are places on the route where the speeds are reduced due to the infrastructure characteristics, and the fact that the bus has to share the road with other users. Given the outcomes of chapter 6, where frequency and speed determine integration, alternatives are developed that try to assess how line 300 can be made more efficient.

7.1.3 Alternatives

As explained, the alternatives need to be able to assess the effects of changes in characteristics of the system for speed and frequency. For the two bus lines that are assessed, different alternatives are developed. The development and modelling of these alternatives is discussed in more detail in the next section (7.2) and in appendix K.

172

As presented in chapter 6 line 172 travels from Kudelstaart in the south-east of Amstelland-Meerlanden to the centre of Amsterdam, has a total length of 29 kilometres, and travels with a speed of 22 kilometres per hour. Line 172 currently offers 6 services per hour during peak-hours, and 3 services per hour in off-peak periods. For line 172, six different alternatives have been developed.

1. ***Base Alternative***
   No changes are made to the existing network, which allows for the comparison of the current service with developed alternatives.
2. ***Frequency Alternative***
   The frequency of the service is increased. For this alternative, the frequency is increased to 10 busses per hour (peak hour), in line with the frequency of the average R-Net line. As only the morning peak is modelled, the frequency is not altered for off-peak periods.
3. ***Speed Alternative***
   The commercial speed of the service is increased. For this increase, dedicated infrastructure is constructed in the modelling environment to minimise the influence of other traffic on the bus service.
4. ***Stop Density Alternative***
   Although no significant relation has been found between the stop density and the catchment area, this alternative is researched as an extra check. This alternative is modelled to see what would happen to the service if one of the characteristics of high quality services is imposed on the network.
5. ***Speed and Frequency Alternative***
   For this alternative, the frequency of the service is increased to 10 busses per hour, and the speed is increased to 30 kilometres per hour through the construction of dedicated infrastructure.
6. ***Speed, Frequency and Stops Alternative***
   In this alternative, the three characteristics of high quality services are combined. Although stop distances do not influence the catchment area (see chapter 6), an increase in distances between stops does influence the speed.

300

As line 300 is already really efficient, both in terms of system performance as well as in terms of integration, it is difficult to use the same alternatives as for 172, as speed and frequency are already optimised. Hence, line 300 is assessed on a more detailed level (at stops and between stops) to determine at which position in the system the system can be improved. Three alternatives have been developed for line 300.

1. ***Base Alternative***
   No changes are made to the existing network, which allows for the comparison of the current service with alternatives.
2. ***Express service alternative***
   For this alternative, an extra bus line is added next to the existing 300 line, and is modelled after line 356, that directly connect Haarlem with Amsterdam without stopping in between, hence creating an express service connecting the most important and strategically positioned stops on the line.
3. ***Tunnel alternative***
   As explained, there are several location in the network of line 300 where high speeds can not be reached. A tunnel could influence the speed, as this tunnel would be a bus-only tunnel, modelled after the existing Abijtunnel that connects De Hoek with Schiphol. Hence this alternative assesses the effect of increased speeds through the construction of a tunnel in the city centre of Haarlem, an area where the bus shares the road with other users.

7.2 Modelling of Alternatives

The alternatives that have been developed in the previous section need to be tested on efficiency. From chapter 6, it is known which characteristics influence transport network integration and to which extend. By modelling the alternatives developed in section 7.1, the effects of these alternatives can be assessed and compared to the current (base) situation of the bus lines. Hence, modelling results will give insight not only in the extent with which characteristics influence the effects of a system, but also gives insight in how these effects influence transport network integration.

This section begins with a small discussion of the chosen modelling method (VENOM in OmniTRANS), followed by a validation study into the usability of this specific traffic model for assessing the effects of transport network integration. Next, the modelling approach of the alternatives of the two bus lines is discussed. Outcomes of the modelling of alternatives are discussed in the next step of the framework (step 5. Assessment of Effects), which is presented in the next section. A more detailed explanation of the modelling of alternatives is presented in appendix K.

7.2.1 Capturing Effects of Integration in a Model

The effects that have to be assessed to be able to state results about the influence of changes in characteristics on transport network integration have been presented in chapter 4. Apart from other societal effects important for the cost-benefit analysis (see section 7.4), the three important effects are:

- The total travel time
- The number of passengers
- The total travel distance

The total travel time has been discussed in detail in chapter 4, where a standardised equations has been presented. The number of passengers is the output generated by the modelling approach used (see the next section). The total travel distance, as explained in chapter 4, is not taken into account in the remainder of this research. The travel time already gives an idea of the possible gains for travellers as the result of increased integration. The total travel distance is a factor that is influenced by the total time budget, and might change in the future as the result of better integration. This can be expected when people can travel further within the same amount of time, thus could result in people deciding to live at a large distance from the activity (e.g. work). As this is a long-term effect of changes in the transport system, this effect is not assessed in further detail.

7.2.2 VENOM

Traffic models can give insight into how the 'resistance' (the ease of transportation) of a trip influences the load on specific sections of a (road) network. Traffic models provide a way to influence and alter characteristics of a network (e.g. speed), and shows what the results would be for the travel load (the number of passengers), and the associated travel time. Hence, Traffic Models can be used to give insight in the first two identified effect,: total travel time and the number of passengers.

For this research, the regional transit model of Amsterdam (VENOM) of OmniTRANS is used. More specifically, OmniTRANS OtTransit is used. This model focusses on the public transport network in Stadsregio Amsterdam, but also includes public transport lines in bordering regions, although on a more aggregate level. OtTransit is a class of OmniTRANS that is used for two main purposes: the assignment of traffic to the network, and the generation of costs of transit ('skims'). With OtTransit, the route choices of passengers can be modelled, based on the transit network, the preferences of the travellers and the costs associated with travel. Hence, OtTransit can be used for this research to determine the change in passenger number when alterations to the transit network are made. Figure 32 presents the different zones of the model, where the colour represent the aggregation level, with in blue the Metropolitan Region of Amsterdam, in yellow the direct surrounding areas, in grey the areas of a more aggregate level, and in pink the highest level of aggregation.

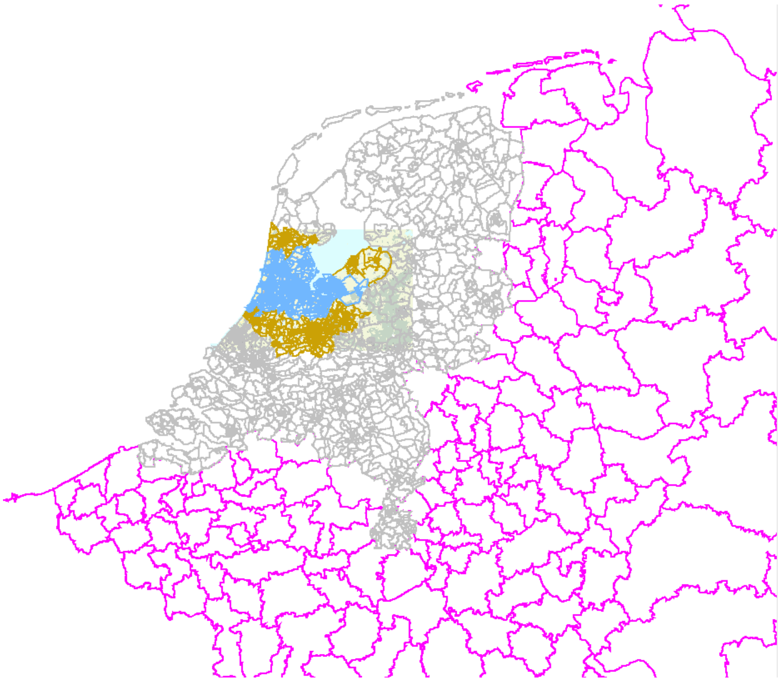


Figure 32: Zones in OtTransit

The public transport network is represented by nodes, which are the bus stops, and bus lines that connect the nodes. The underlying network of links represents the infrastructure over which the busses drive, and contain information about speed limitations on the link and capacity limitations. In different cube matrices, information about the origins and destinations of passengers is stored. By running the model, the passengers are assigned to a certain trip, depending on the costs of this trip (e.g. consisting of the travel time, access time, number of transfers and waiting time).

7.2.3 Validation of the Model

To be able to use the model to assess system effects, the model has to be validated. In this research validation is tested in two different ways:

- The model behaviour is validated. The behaviour is validated by comparing the usage of the bus stops in OmniTRANS with the usage of the bus stops as derived from GOVI data.

- The model outcomes are validated, which means the number of passengers that are modelled in OmniTRANS can not deviate too much from passenger data in real life operations.

Validation of Model Behaviour

In this first validation step, the behaviour of the model is tested. If the model is a valid method to use for the assessment of transport integration, the behaviour of the model should be comparable to the behaviour of the system in real life.

To test the behaviour, the stop usage is assessed. The stop usage indicates how often a stop is used. Usage of stops is determined using GOVI data. OtTransit can generate stops based boarding/alighting passenger numbers, and thus shows the relative percentage of usage of the stops. Furthermore, OtTransit generates boarding/alighting graphs as presented in Figure 33.

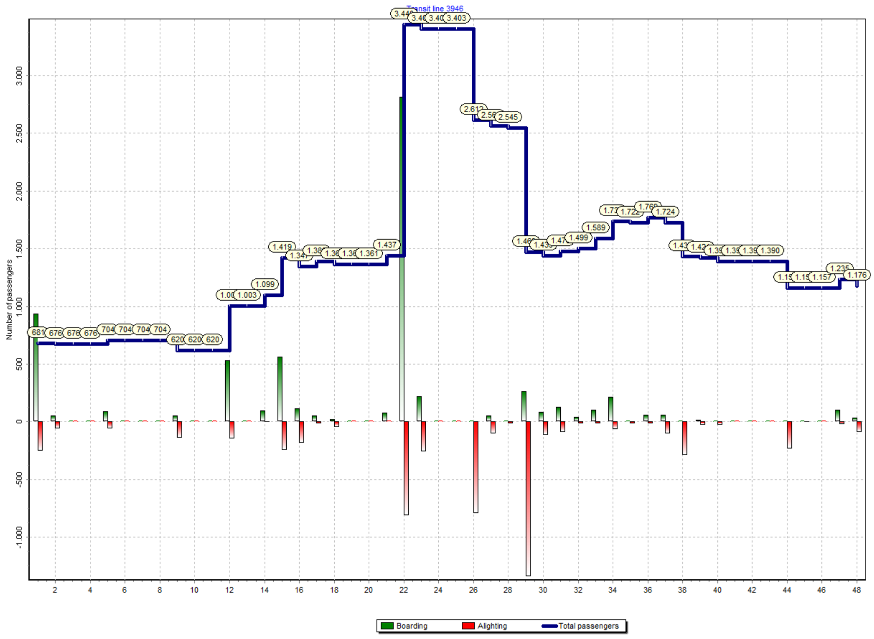


Figure 33: Boarding and Alighting Graph of Line 300

The validation for model behaviour results in certain stops that are used less than in real life, or more than in real life. Appendix J shows the stops usage for line 172 and for line 300 and presents the difference between these two (in a percentage). There are several differences that are rather high.

On average, the difference between usage in reality and model usage is -0,9% for line 172 and 0,6% for line 300. Hence, with these outcomes, it can be concluded that both the modelling behaviour as well as the model outcome are validated, and that as such the model can be used to assess the transport networks.

Validation of Model Outcomes

Next, the model outcomes are validated. The model can be used when the outcomes of the base scenario in the model are comparable to the outcomes (effects) of the system in real life. The results of the first validation step are presented in Table 26.

Table 26: Validation of Model Outcomes

Busline	172	300
Number of Passengers Base Alternative	187436	621501
Number of Passengers Qlik Data March 2015	177093	600206
Percentage Comparable	94%	97%

This table presents the number of passengers for the two assessed bus lines, both for the model, as well as for the number of passengers derived from Qlik data for March 2015. As can be seen in the table, the difference between the model and the real life data is 6% for line 172 and 3% for line 300. As such, overestimates the number of passengers by 3-6%. This is an acceptable overestimation, and hence, the model is validated model outcomes.

7.2.4 Modelling of Bus Line Alternatives

Appendix K shows the different alterations that have been made to the OmniTRANS model and the two bus lines to assess integration. Note that all alternatives are modelled and run separately, as to ensure results are not influenced by alterations in other lines or characteristics.

7.3 Assessment of Effects

The previous sub-section presented the modelling approach of the two bus lines. This section discusses the system effects of the different alternatives.

7.3.1 Number of Passengers

The first effect that is discussed is the number of passengers. Table 27 and Table 28 present the number of passengers for the two assessed lines per alternative.

Table 27: Number of Passengers for Alternatives of line 172

172	# morning	factor	# day	month	# year (week days)
Base	1348	6,95	9372	187436	2436667
Frequency	3827	6,95	26598	531956	6915425
Speed	4406	6,95	30619	612384	7960991
Stops	964	6,95	6701	134014	1742183
Freq & Sp	2896	6,95	20125	402501	5232512
Frequ-St-Sp	9081	6,95	63111	1262212	16408753

Table 28: Number of Passengers for Alternatives of line 300

300	# morning	factor	# day	month	# year (week days)
Base	7506	4,14	31075	621501	8079512
Plus Express	7138	4,14	29551	591016	7683203
Tunnel	8959	4,14	37088	741769	9642994

In the next step of the framework, the different alternatives are compared. As in that step a societal Cost-Benefit Analysis (CBA) is used, the number of passengers has to be expressed in number of passengers per year. However, the number of passengers derived from VENOM is based on the morning rush hour. For the base scenario, both morning and evening peak hour, as well as 'rest of the day' are modelled once to determine a 'factor' with which the morning outcomes have to be multiplied to represent daily number of passengers. From Table 27 and Table 28, it can be seen that the factor for line 172 is 6.95, and for line 300, this factor is 4.14. All outcomes of the morning rush hour runs are multiplied to determine the daily amount of passengers, with which in turn the monthly and eventually yearly passenger numbers can be determined. Note that these numbers only represent week days, weekends are not taken into consideration.

For line 172, a decrease in passenger numbers can be observed for the stop alternative. This can be explained by the search method of VENOM. A passenger searches for the most optimal stop (e.g. in terms of travel time, frequency of service and number of transfers) in a search radius of 5 kilometres. When the stop density is decreased, there is a large chance that other services are closer, faster or more frequent, and thus a passenger changes its trip and no longer uses line 172. All other alternatives show an increase in passenger number for line 172, with the frequency, stop and speed alternative showing the largest increase. This seems odd, as this alternative also includes the decrease in stop density. Apparently, the positive effects of speed and frequency cancel out the negative influence of the larger distance between stops.

Table 28 presents the passenger numbers per alternative for line 300. Adding an express service does not increase, but decreases the number of passengers. This can be explained by the nature of the alternative: the addition of an express service (4 times per hour) decreased the frequency of the non-express service (from 10 to 8 times per hour). Apparently, this decrease in frequency influences the number of passengers more than an increase in speed for a (smaller) group of passengers that will use the express service. The tunnel alternative increase the number of passengers using the bus line.

7.3.2 Total Travel Time

The next effect that is assessed for the different alternatives is the total travel time. As explained in appendix J, venom does not allow to model or generate output about the access and egress times. As explained the relations identified in chapter 6 imply that an increase in frequency of the service or an increase in speed of the service generates an increase in the catchment area. People are willing to invest more time in access/egress if the bus section of the trip is faster/more frequent (lowering the in-vehicle time or lowering the hidden-waiting time). Thus, the access and egress times have to be determined for these alternatives based on the previously stated trend lines (chapter 6). As explained in chapter 6, the frequency and speed show a positive, significant relation derived from regression analysis. The factors generated from this analysis can provide a way to determine access and egress times.

Section 6.2.2 in showed the regression outcomes for speed access (walking) speed egress (walking), frequency access (walking) and frequency egress (walking). For the bicycle, these values did not show to be significant. Therefore, the access and egress determination of this part of the research is only based on walking (it makes no sense to calculate differences in cycling catchment area when these values are not significant).

The equations used to determine the total travel time has been presented in chapter 6. Table 29 presents the different values of the parameters of the equation for the different scenarios (recall the total travel time equation of chapter 4). The last column presents the total travel time.

Table 29: Travel Time Components and Calculation of Total Travel Time per Alternative

172	Th	ma	Ta	Mw	Tw	Tiv	me	Te	HT	TT
Base	10	1,65	0:08:55	1,7	0:01:02	0:27:00	1,65	0:06:43	0:10:00	1:04:35
Frequency	6	1,65	0:10:34	1,7	0:01:02	0:27:00	1,65	0:10:34	0:06:00	1:09:36
Speed	10	1,65	0:07:34	1,7	0:01:02	0:20:00	1,65	0:07:34	0:10:00	0:56:42
Stops	10	1,65	0:08:55	1,7	0:01:02	0:27:00	1,65	0:08:55	0:10:00	1:08:12
Catchment	10	1,65	0:08:55	1,7	0:01:02	0:27:00	1,65	0:08:55	0:10:00	1:08:12
Freq & St	6	1,65	0:10:31	1,7	0:01:02	0:27:00	1,65	0:10:31	0:06:00	1:09:27
Frequ-St-Sp	6	1,65	0:10:19	1,7	0:01:02	0:20:00	1,65	0:10:19	0:06:00	1:01:49
300		ma	Ta	Mw	Tw	Tiv	me	Te	HT	TT
Base	6	1,65	0:09:08	1,7	0:00:34	0:16:00	1,65	0:06:43	0:06:00	0:49:08
Express	6	1,65	0:09:43	1,7	0:00:34	0:13:00	1,65	0:09:43	0:06:00	0:52:02
Tunnel	6	1,65	0:09:26	1,7	0:00:34	0:14:00	1,65	0:09:26	0:06:00	0:52:05

It might be that the faster or more frequent trip takes longer to complete in total. This calls for further research in the valuation of transport service by passengers of access and egress. The multiplier for the penalty (discussed in chapter 4), is heavily influenced by the characteristics of the bus, meaning that people might be willing to travel longer on the access and egress side and for the total trip if the bus part of the trip is shorter in time. Hence, it could be that a different multiplier is needed to valuate access/egress time and waiting times. However, determining these multipliers lies beyond the scope of this research. Hence, the multipliers are used in the remainder of this research, but this calls for some caution when interpreting the values.

Table 29 shows that, with the above explanation, an alternative with higher in-vehicle speeds not necessarily results in a lower total travel time, due to the use of multipliers and the use of an increased catchment area as the result of positive changes in bus characteristics. For example, the frequency alternative of line 172 has no changes in in-vehicle time as compared to the base scenario. However, due to an increase in frequency, the catchment area increases as well. Hence, the total travel time increase due to an increase in access and egress distances (and thus times).

7.4 Comparison of Alternatives

The final step of the assessment framework involves the comparison of different systems and their alternatives. To assess and compare the performance of the alternatives, a Cost-Benefit Analysis is carried out. Appendix M presents the detailed CBA. The following sub-sections presents the step-wise construction of the two CBAs, one for line 172, and one for line 300.

7.4.1 Construction of the CBAs

As presented in chapter 4, two different effects of integration have already been discussed: the total travel time and the number of passengers. For this research, it is important to identify the different (monetised) effects of alterations in the transport system for different alternatives.

Cost-Benefit Analysis

A Cost-Benefit Analysis (CBA) is an assessment tool that helps with the justification of (large) transport projects. The effects of such a project can be listed, and expressed in monetised values. A CBA is a method that can be used to test the effectiveness of transport alternatives (do the alternatives realise a certain ambition/goal) and the efficiency of the alternatives (do the benefits of the alternative outweigh the costs). This research presents a 'light' version of a societal CBA. The 'light' implies that this CBA is used as an exploratory rather than an advanced assessment tool. The societal CBA revers to the fact that the CBA has been constructed from the viewpoint of society as a whole. This implies that the CBA is not merely used to assess if the benefits can cover the costs (in monetised units), but takes into account the effects of all involved actors. As such, a societal CBA is not merely constructed from the viewpoint of one specific stakeholder (e.g. Stadsregio Amsterdam), but takes into account other actors as well (e.g. the passengers). With this societal CBA the effects of alternatives are compared with the situation without alterations (the base alternative). The different effects that are assessed in this 'light' societal CBA are discussed in the following sub-section. As a guidance for the construction of the CBA, two different references have been used. The 'Leidraad OEI' (Eigenraam, Koopmans, Tang, & Werster, 2000) is a program developed by the Dutch government in which the process of societal CBA is discussed. The guidebook 'Societal CBA' (Romijn & Renes, 2013) is an updated and modernised version of the 'Leidraad OEI'.

7.4.2 Calculations and Monetisation of System Effects

Identification of Effects to be assessed

The value of the effects of the different alternatives as presented in section 7.1 can be calculated and subsequently monetised. For a societal CBA, three different types of effects can be identified:

- Direct effects, which are effects that are important for the owner of the project, in this situation the concession authority of Amstelland-Meerlanden, being Stadsregio Amsterdam. These effects include costs of construction of project alternatives, maintenance and exploitation, and benefits of operations both for Stadsregio Amsterdam as well as for the passengers using the system.
- Indirect effects, that influence markets other than the directly involved transport system. Examples of such effects are long term effects on the job- and housing markets.
- External effects, which influence the system and its environment but are not directly experienced by the owner or user of the system. This includes environmental effects, for instance emissions.

As the CBA in this research is a societal 'light' CBA, not all three effects as identified are assessed in the greatest level of detail. As such, the indirect effects of the alternatives are not taken into account. The external effects of the alternatives are not calculated separately, and are as such not quantitivly assessed. These effects are expressed qualitatively, and either have a positive (PM positive) or negative (PM negative) outcome.

Monetisation of Effects

Direct effects

As explained earlier, the direct effects influence both the owner of the project (Stadsregio Amsterdam) as well as the users of the transport system under consideration (the passengers). The effects can either be costs, or benefits.

The costs can be split in two different types: the investment costs, which are to be paid in full in the first year, and the operational costs, which are the result of alterations in the system, and are influenced by the frequency of service of the network. Appendix M presents different tables where the investment costs and the operational costs are calculated per alternative. Table 30 summarises these monetised effects.

Table 30: Summary of Monetised Effects

Measure	Year	Price (€)	Inflation Correction	length (km)	price per km
Bus stop	2015	27000	27000	-	-
Infrastructure	2002	231600000	266050000	40	6651250
Tunnel	2002	62000000	36134500	1,8	20074722,22

The price of the bus stop has been determined by Stadsregio Amsterdam. This is the price of alteration of existing bus stops to upgrade a conventional stop to R-Net standards. The costs for infrastructure are the costs per kilometre of dedicated infrastructure. Note that these costs are based on the existing Zuid-Tangent. These bus ways have been constructed to support both bus services as well as tram services. As such, this is a rather high estimation of infrastructure costs. The tunnel (for the line 300 alternative) is based on the Abdijtunnel connecting De Hoek with Schiphol.

The operational costs of busses in Amstelland-Meerlanden have been based on calculations from Stadsregio Amsterdam. The operational costs are €110 per bus per hour. This number includes bus driver wages and fuel expenditures.

The benefits can either be benefits for the operator (or owner, in this case Stadsregio Amsterdam and Connexxion as the bus operator). And benefits for the passengers. Operator benefits include income from operations, which has been determined to be €0,17 per traveller kilometre, as well as subsidies from governments. These subsidies are granted by Stadsregio Amsterdam and cover a maximum of half of the operational costs. When the operational benefits can not cover at least half of the operation costs, the operations of the service financially compensated by Stadsregio Amsterdam.

The benefits for passengers are the travel time benefits. In this research, the travel time is calculated for the entire journey (from origin to destination) as opposed to just the travel time in the bus link, which is used in most other cases. This incorporation allows for the monetisation of the entirety of passenger benefits, instead of just one part of the transport chain.

To be able to calculate the travel time gains (in €) the total travel time, as presented in Table 29 is used. Table 31 and Table 32 present the calculations of the travel time gains for passengers in the different alternatives.

Table 31: Calculations of Travel Time Gains for Alternatives of Line 172

Alternative	Travel Time (hours)	Delta time (hours)	Existing Passengers Base (#)	Total Passengers (#)	New Passengers (#)	VoT (€/hour)	Rule of Half (€/hour)	Total Travel Gains (€)
Base	1,076	0,000	2436667	2436667	0	6,28	3,14	0
Frequency	1,160	-0,084	2436667	6915425	4478758	6,28	3,14	-2461590
Speed	0,945	0,131	2436667	7960991	5524324	6,28	3,14	4282663
Stops	1,137	-0,060	2436667	1742183	-694484	6,28	3,14	-793658
Freq & St	1,157	-0,081	2436667	5232512	2795845	6,28	3,14	-1955051
Frequ-St-Sp	1,030	0,046	2436667	16408753	13972085	6,28	3,14	2724456

Table 32: Calculations of Travel Time Gains for Alternatives of Line 300

Alternative	Travel Time (hours)	Delta time (hours)	Existing Passengers Base (#)	Total Passengers (#)	New Passengers (#)	VoT (€/hour)	Rule of Half (€/hour)	Total Travel Gains (€)
Base	0,819	0,000	8079512	8079512	0	6,28	3,14	0
Plus Express	0,116	0,703	8079512	7683203	-396309	6,28	3,14	34782525
Tunnel	0,868	-0,049	8079512	9642994	1563482	6,28	3,14	-2745930

The travel times as calculated in Table 29 have first been translated to number instead of time measurements. The difference in time has been calculated for the alternatives as compared to the base alternative (delta time). Next, using the passenger number of the base alternative (existing passenger base) and the different alternatives (total passengers) the new passengers per alternative can be calculated. For existing passengers, the travel time gains (benefits or costs) are experienced in full, whereas for the new passengers, only half of the benefits is experienced (rule of half). The Value of time (VOT, also explained in chapter 4) monetises travel time gains of travel time loses. A value of time of €6.28 per hour has been chosen for this research (Romijn & Renes, 2013). The last column of the tables presents the total travel time gains per alternative.

7.4.3 Cost-Benefit Analysis of Alternatives

With the calculation and monetisation of effects in the previous sub-section, the CBAs per bus line can be developed. Appendix M presents the detailed CBA of every alternative. For these CBAs, a discount rate is used of 5,5%, which consist of 2,5% risk-free discount and 3% risk premium. The CBAs of the two lines are presented in Table 33 and Table 34

Table 33: Cost-Benefit Analysis Line 172 (in millions of euros)

		Base	Frequency	Speed	Stops	Frequency and speed	Frequency, speed, stops
Costs							
Investment Costs		0,0	1,5	68,0	0,8	68,0	68,0
Operational Costs	€110/bus/hour	2,1	93,3	12,2	62,8	12,7	12,7
Benefits							
Operator Benefits							
Income from Operations	€0,17/traveller kilometre	3,6	169,3	62,3	87,2	6,4	13,7
Stadsregio Subsidies	Max 0,5*operational costs		0,0	0,0	0,0	6,4	6,4
Passenger Benefits							
Travel Time Gains			-38,2	24,5	-23,3	-1,8	-2,0
External Effects							
Emissions	PM1	0	-	-	0	-	-
Noise	PM2	0	-	-	0	-	-
Traffic Safety	PM3	0	-	-	0	-	-
TOTAL			36,2	12,6	0,3	-69,8	-62,6

Table 34: Cost-Benefit Analysis Line 300 (in millions of euros)

		Base	Express Service	Tunnel
Costs				
Investment Costs		0,0	0,0	34,1
Operational Costs	€110/bus/hour	6,0	130,6	34,3
Benefits				
Operator Benefits				
Income from Operations	€0,17/traveller kilometre	10,0	81,6	89,5
Stadsregio Subsidies	Max 0,5*operational costs		0,0	0,0
Passenger Benefits				
Travel Time Gains			540,3	-15,7
External Effects				
Emissions	PM1	0	-	-
Noise	PM2	0	-	+
Traffic Safety	PM3	0	-	+
TOTAL			491,3	5,4

Table 33 and Table 34 show the CBAs of the two assessed lines. The investment costs are determined based on the costs presented in Table 30, where every alternatives for line 172 has investment costs for the refurbishment of the bus stops to stops of R-Net quality. For the stop alternative of line 172, the investments costs are lower as compared to the frequency alternative, due to the fact that the stop alternative has less stops that need refurbishment. The express service alternative of line 300 has no investment costs, it is assumed that extra vehicles and bus drivers are readily available. As explained, the operational costs are determined based on the frequency of the service and a cost of €100 per bus per hour. The operator benefits are determine by calculating the total number of passengers (Table 31), multiplied with the average in-vehicle distance (which has been determined by the survey outcomes, and is presented in Table 35), and the income of €0,17 per traveller kilometre.

Table 35: Average distances travelled

Line number	172	300
Average travel distance (km)	7,275	8,637

The subsidies of Stadsregio Amsterdam (a maximum of half of the operational costs) have only been assigned to two alternatives that turned out negative, being the frequency and speed alternative, and the frequency, stop and speed alternative. Addition of subsidies however, does not make the costs outweighed by the benefits.

For line 172, the frequency alternative is most positive. No large investments, apart from stop refurbishments has to be made, while the number of passengers and as such the income from operations increases. However, the passenger benefits for this alternative are negative: this is explained by the use of total travel time rather than just the in-vehicle travel time. As the total travel time is influenced by an increase in catchment area, the travel time gains become negative. As such, it is important to further research the influence of the use of total travel time, including acceptance of longer access and egress times when in-vehicle times are shorter (speed alternative) of hidden waiting times are diminished (frequency alternative), as outcomes are now rather skewed.

For line 300, both alternative are positive, although the express alternative shows a much higher benefit outcome of 491 million euros. Table 28 showed that the number of passenger decreases for this alternative. However, as presented in Table 32, the travel time gains are tremendous for this alternative. Hence, the decrease in the number of passengers (and as such the operational income) is compensated by the positive travel time gains of the existing passengers.

7.5 System Effects and Transport Network Integration

With the final part of the assessment framework (part B. Effect Assessment), the influence of altering characteristics in the transport network in the system effects has been tested. Three effects have been presented in chapter 4 as being important to assess the influence of transport integration on these effects. These are:

- The total travel time
- The number of passengers
- The total distance travelled

Given the relation between system causes and effects, one would expect that when adapting the characteristics of the system, the effects would be influenced positively. This final step in the framework, that determines how integration improvements influence effects of the system, is important to verify the adaptation of the system to increase integration. As for the three identified system effects, the first two are influenced by integration. The final effect (total distances travelled) is a long-term effect that has to be determined based on people being able to travel longer distances within the same time (Total travel time budget). These effects have not been assessed in this research, and thus no conclusion can be drawn for the influence of optimising integration on total distances travelled.

For the other two, the following conclusions can be drawn.

Total travel time

The total travel time has been mentioned many times before. Alterations in the different time components of the equations influence the total travel time. However, even though the in-vehicle time might decrease due to changes in transport characteristics, the total travel time might still increase. This is the result of how the total travel time has been determined, and of how the Ta/Te (access and egress travel times) have been determined. Access and egress times are calculated using the regression equation that has been found in chapter 6. These values are then multiplied by the multiplier from chapter 4. However, these multiplier are static, and do not explain that people might be willing to invest in longer access and egress times if the in-vehicle time is shorter. Hence, it is important in future research, to reassess the multiplier specifically for determining the total travel time in integrated networks, taking into account the possible benefits of increasing the trip on the access/egress side.

Number of Passengers

When a certain trip becomes more beneficial to people, more passengers will use that trip to get to their destination. Whether or not this increase in passengers is the result of alterations in the transport system has been determined using OmniTRANS as a modelling environment. Section 7.3 showed that for changes in trip frequency and speed, the number of passengers increased. This is in line with was expected: chapter 6 showed a relation between catchment area size (which stressed integration) and frequency and speed.

7.6 Conclusion

The final part of the assessment framework consisted of assessing the effects of transport network integration. By analysing different characteristics of the transport system in chapter 6, characteristics that influence integration have been identified. These characteristics have then been used to develop different alternatives. These effects of these alternatives, as identified in chapter 6, have been assessed and compared using a CBA.

Q11: How does integration influence the effects of the transport network?

When characteristics of the transport system that influence integration, as presented in chapter 6, are altered, the effects of the system change as well. Section 7.3 has shown that for alternatives where the speed of the service or the frequency of the service is altered, the number of passengers increases. As explained in section 7.5, the travel time is influenced by alterations in characteristics as well. However, even though the in-vehicle time might decrease due to changes in transport characteristics, the total travel time might still increase, which is the result of the calculations of access and egress times based on increases in catchment areas. As such, integration influences both the number of passengers, as well as the total travel time.

Q12: Which conclusions can be drawn from effect assessment for the systems under consideration in the case study?

Given the relation between system causes and effects, one would expect that when adapting the characteristics of a system, the effects would be influenced as well. This part of the framework (effect assessment) has verified that the by changing the characteristics of a system, the effects change too. For the total travel time, is has been shown that the total travel time can increase even though the in-vehicle travel time (speed) or the hidden waiting time (frequency) decrease. This is explained by the fact that people are willing to travel longer distances on the access and egress sides (catchment area increases). However, since (static) multipliers are used to determine the access and egress sides (based on the distances), the results can be slightly biased. It could be that for different types of services, the multipliers differ in value, hence stressing the need to research the differences in multipliers for different systems. Apart from the travel time, the changes in characteristics of the service saw an increase in the number of passengers (apart from the stop density alternative, which showed a decrease).

8. Conclusion and Recommendations

In this report, a framework has been developed with which transport network integration in bus systems can be assessed. This chapter starts with the answering of the sub-research questions that have been presented in chapter 1. With these sub-questions, the main research question can be answered. Next, this chapter discusses the usability of the developed framework, and presents conclusions of importance for Stadsregio Amsterdam, derived from the case study. Finally, this chapter finishes with recommendations.

8.1 Answering the Sub-Research Questions

Every chapter in this thesis concluded with the answering of the sub-research questions. These answers are summarised in this section, and help in determining the answer to the main research question (see section 8.2).

Literature Review

Question 1: What types of transport network integration can be distinguished, and which definition of transport network integration is used in this research?

Four types of transport network integration have been presented:

- Physical integration, which entails seamless trips, where transfer facilities (between modalities) are improved;
- Network integration, where different hierarchical levels of the transport system are integrated;
- Fare integration, where an integrated ticketing system over the entire network is provided;
- Information integration, where information for all modalities is available.

Physical integration and network integration are the main types of integration used and assessed in this research. Transport network integration can be described as *the combination of individual elements of the transport chain, from a travellers' origin to its destination, with the aim to positively influence the performance and effects of the transport system. This combination entails the integration of the different elements (modalities) through improvement of the performance of mode specific characteristics that influence integration, taking into account the environment of the entire system.*

Question 2: What challenges exist for transport network integration?

Challenges of integration can be used to its advantage in the development of the assessment framework. Three challenges have been identified in chapter 2:

- The concept of multi-modality in integrated networks and the importance of multi-modality for travelling longer distances;
- Network integration, where different levels of the transport system are integrated;
- Fare integration, where an integrated ticketing system over the entire network is provided;
- Information integration, where information for all modalities is available.

Question 3: How can transport network integration be assessed?

As presented in chapter 2, three methods of assessment of integration have been used in the past. These are:

- Integration through assessment of nodal (transfer) points;
- Integration through assessment of societal analysis and policy making;
- Integration through network analysis.

These three methods fail to capture the entire concept of transport network integration, and do not give an explanation of both the causes and effects of transport network integration. As such, the framework needs to be able to address and assess:

- The influence of network specific characteristics on transport network integration;
- The influence of the integrated transport system on (societal) effects;
- The assessment and comparison of different systems in terms of performance characteristics and effects.

Q4: What elements and can be identified in the integrated bus-NMT network?

Chapter 3 provided a definition of a system, which consists of several parts (the system elements) and their attributes (characteristics). The system influences and is influenced by its environment, and the total of all elements result in effects (outcomes) of the system. Chapter 3 identified six different elements for the integrated bus-NMT system: the access link, the access node, the bus link, the egress node, the egress link and the environmental elements. With the characteristics of these elements, that can be expressed in a certain value, the performance of the system can be assessed, which is used in the framework.

Q5: Which characteristics of elements that could potentially influence transport network integration in bus networks should be considered?

Chapter 2 discussed the emergence and design of the different elements of the integrated transport system. Using literature, characteristics, design considerations and implications for transport network integration have been researched. In chapter 3, a list of characteristics of the different elements has been presented.

For the access and egress links, the relation between characteristics of the dominant modality (the bus) and its influence on the catchment area are important. Furthermore, cycling proves to be a high potential modality that offers a flexible access/egress mode complementary to the bus system, and allows for travelling longer distances in the access and egress side of the trip as opposed to walking. Other aspects that have to be taken into account when assessing integration of bus systems with NMT are the differences in characteristics between the two NMT modalities (walking and cycling).

For the bus link, factors that need to be taken into account include differences in service between lines and characteristics between conventional and high quality bus systems, and the influence of these characteristics (e.g. frequency, reliability) on integration and performance of the system. Furthermore, several design dilemmas have been identified that have to be taken into account when considering public transport performance and integration.

For transfer nodes, the access or egress modality is important to consider, as this influences the catchment area of the transfer node (the bus stop). Finally, when considering the environmental elements of the integrated system (spatiality and demographics) it is important to consider the influence of these characteristics on the travel behaviour, as this influences travel demand.

Framework Development

Q6: Which considerations need to be taken into account for the development of the assessment framework?

With the assessment of transport network integration in literature, and the description of the integrated transport system, several consideration can be identified that need to be captured in the assessment framework:

- *The influence of network specific characteristics on transport network integration;*
  Implies that the framework should be able to identify and assess different characteristics of the system elements, and should be able to determine the influence of these characteristics on network integration.
- *The influence of the integrated transport system on (societal) effects;*

Implies that the framework should be able to determine the effects of a system, and should be able to determine the influence of network integration on these effects.

- *The assessment and comparison of different systems in terms of characteristics and effects.*
  Implies that the framework should allow for the comparison and improvement of different bus systems.

Q7: How can de different elements of the transport system, including their specific characteristics, be captured in one assessment framework?

To be able to incorporate these considerations in the framework, the distinction has to be made in two types of assessment: assessment of the bus networks, and assessment of integration. The assessment of integration is the result of a comparison of different bus systems (bus lines) in the first assessment type. For the assessment of the bus lines, two steps are important, being the assessment of the performance of the bus lines, and the assessment of the effects of the performance. Hence, the assessment of elements can be captured in the framework by assessing three different steps:

- *Bus Line Performance Assessment;*
  Which involves the assessment of the different system elements and their characteristics of different (types of) bus services, including a comparison between different bus lines.
- *System Effect Assessment.*
  Which involves the assessment of the effects of the (optimised) integration of the individual systems, including a comparison between bus lines.
- *Integration Assessment,*
  Which involves the assessment of the manifestation of integration in transport networks and the related integration effects.

The assessment framework is presented in Figure 34.

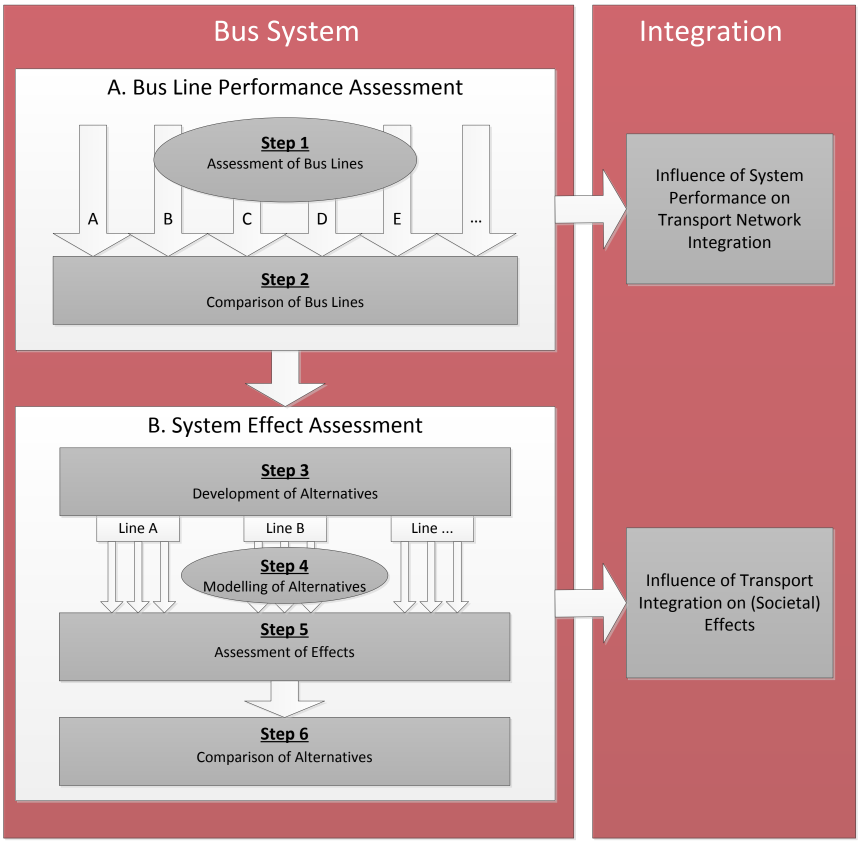


Figure 34: The Assessment Framework

Q8: Which characteristics of the elements of the transport system are assessed with the framework?

Environmental Elements	• Level of Urbanisation	• Activities around a bus stop
Access and Egress Elements	• The catchment area in time • The catchment area in distance	• The mode choice for access and egress
Bus Network Element	• Stop Density • Reliability of the service • Commercial speed • In-vehicle time	• Frequency of the service • Percentage of dedicated infrastructure
Transfer Elements	• The waiting time at the bus stop	• The usage of the bus stop

Case Study

Q9: Which data is needed for the case study?

A case study is conducted for the concession area Amstelland-Meerlanden of Stadsregio Amsterdam. In order to assess the integration in this area, the following data input is needed:

- Zonal Data, which relates to environmental specific data (spatiality, demographics) at the level of the four digit (4PC) postal codes.
- Survey data, which gives insight in the travel behaviour and travel choices of passengers
- GOVI data, with which the performance of the bus systems can be assessed.
- Ridership data as collected from the Stadsregio Amsterdam Qlik database.

Q10: Which specific characteristics (e.g. network design) of elements influence network integration?

To be able to answer this sub-question, the different steps of the first part of the assessment framework (A. bus line performance assessment) are conducted for the case study.

Step 1: Assessment of Bus Lines

The first step involves the assessment of individual bus lines. The different bus lines are assessed on elements and characteristics mentioned earlier, and are compared using a scorecard in step 2. General survey outcomes give a chance to give a general overview of system performance of the 10 assessed bus lines. The break-down of use of access and egress modalities for the bus lines is most important. This break down emphasises the need for more detailed knowledge in the use of access and egress modalities for bus networks. In literature, a lot is known about access and egress modalities for train services, especially in the Netherlands. This research gives insight in the access and egress modalities for bus networks, which is then compared to break down for train services and give insight in the differences in behaviour for the different modalities (bus versus train). The bicycle is an important modality on the access side, whereas its share on the egress side is much smaller. This can be explained by the fact that on the access side of a trip, people often have more modalities at their disposal, and thus have a larger choice of modalities. On the egress side, these modalities are often not or less available. Furthermore, walking is more important on the egress side, suggesting distances on this side of the trip are often shorter, hence allowing for walking. These outcomes stress the importance of the bicycle on the access side, where for bus systems, walking and cycling are very often considered as one modality. Hence, it is important to consider cycling and walking as access and egress modalities separately to ensure integrated networks. Furthermore, the high use of the bus on both the access and egress side suggest that other bus services are important as feeder services to faster or last-mile bus services. Opportunities might exist on the egress side of the trip (last-mile) if these distances are short, for instance through the supply of cycle-hire facilities, thus aiming for competition between bus and bike for short last-mile distance.

Step 2: Comparison of Bus Lines

The bus system (lines) are compared in three different ways: by bus type, by bus line, and by stop.

The bus type comparison compares Comfortnet (conventional bus system) with R-Net (high quality bus-system). Striking is that for R-Net, the share of the bike, both for access and egress trips, is much higher than the share in Comfortnet lines (25% versus 11% access, and 10% versus 5% egress). One explanation could be that people accept longer trips for R-Net services due to the positive performance differences between R-Net and Comfortnet (e.g. higher speeds, higher frequencies). The accepted distances for access and egress for walking and cycling have been assessed in more detail. For R-Net, distances are often higher than for Comfortnet, with the exception of the bicycle use on the egress side. This exception is explained by the low number of observations for walking trips for Comfortnet services. Due to overestimation of distances, caused by the use of 4PC instead of the more detailed 6PC, a correction for distances has to be made. In the remainder of the research, for cycling, the 75th percentile is chosen as the upper boundary for the catchment area, for walking, this is the median.

The line based comparison allows for a more detailed comparison of the ten assessed bus lines. The previously mentioned characteristics per element are assessed. Using the equation for total travel time, the travel times per line can be determined for an in-vehicle distance of 10 km, hence allowing to compare the differences in speed, frequency and access and egress times. Using the outcomes of the bus line comparison, relations that determine integration can be assessed. The following relations have been assessed using regression analysis:

- Stop density and catchment area (no significant relations)
- Service of speed and catchment area (significant relation for walking on the access side)
- Service frequency and catchment area (significant relation for walking on both the access as well as the egress side)

The non-significance of walking on the egress side and cycling could be explained by the smaller number of observations for these links. The same goes for the non-significance of cycling in the frequency versus catchment area relation.

Finally, the stop based comparison allows to consider elements from the environment that influence travel choice and integration. Three assessment have been conducted, the assessment of spatial levels, the assessment of activities, and the assessment of type of bus stop (access or egress). A regression analysis has shown that there is a relation between the spatial level (1 for extremely urbanised, 5 for rarely urbanised) and the catchment area of the bus stop. The directions of these relations are different for Comfortnet and R-Net. For Comfortnet, the catchment radius increases when the spatial level decreases, for R-Net, this is the other way around. The assessment of activities has shown no significant relations. This could be caused by the use of 4PC to assess activities. This more general zonal level (instead of the more detailed 6PC) results in rather large regions that can be assigned as 'residential', while there is a large educational facility that attracts the largest number of passengers. The final assessment, the type of bus stop, has shown that for access stops, people travel longer distances by foot (not that this is the activity based side), probably because of the lack of availability of other modalities. On the egress side (home-based), distances for egress stops are shorter than for non-classifiable stops.

Q11: 1. How does integration influence the effects of the transport network?

To be able to answer this question, the final four steps of the assessment framework are explained.

Step 3: Development of Optimisation Alternatives

The previous steps have shown that two characteristics contribute to an increase in integration. For two bus lines in Amstelland-Meerlanden, one Comfortnet line and one R-Net line, alternatives are developed to determine the influence of the identified characteristics (integration) on the effects of the systems. For the Comfortnet line, six alternatives are considered (base alternative, frequency increase, speed increase, decrease in stop density, speed and frequency, and finally speed, frequency and stop distances). For the R-Net line, three alternatives have been generated (the base alternative, the express service alternative (skipping stops) and the tunnel alternative (allowing for a higher service speed)).

Step 4: Modelling of Alternatives

The different alternatives are modelled and assessed using a traffic model. The traffic model used is the transit model of VENOM, the regional model of Stadsregio Amsterdam. OtTransit is a class of OmniTRANS that is used for two main purposes: the assignment of traffic to the network, and the generation of transit costs (skims). The model has first been validated for use. By comparing the number of passengers (Qlik data of March 2015) with the modelled number of passengers, the model is validated based on outcomes. By comparing the usage of bus stops (GOVI data) with the usage of bus stops in the model, the behaviour of the model is validated.

Step 5: Assessment of Effects

The different alternatives are modelled and compared. This comparison allows for the calculation of total travel times, using the previously mentioned total travel time equation and the equations for the catchment area. This leads to the travel times as presented in Table 29. These travel times will be used in a Cost-Benefit Analysis (CBA) in step 6 to compare the effects of the different alternatives. The assessment of effects has also shown that when the characteristics that influence integration are altered, the number of passengers increases.

Step 6: Comparison of Systems

The performance of the different alternatives, in terms of travel time and number of passengers, is done using a Cost-Benefit Analysis (CBA). This CBA allows to assess the alternatives on societal viability by taking into account both the costs of implementation of these alternatives (e.g. operational costs, implementation costs), as well as the benefits (travel time savings, increase in operational income through the increase in number of passengers). This analysis shows that for line 172, the frequency alternative and the speed alternative give a positive outcome. For line 300, both developed alternatives are positive, but the express service alternative has shown a tremendous increase in monetise benefits as compared to the base scenario.

Q12: What conclusions can be drawn from effect assessment for the systems under consideration in the case study?

Given the relation between system causes and effects, one would expect that when adapting the characteristics of a system, the effects would be influenced as well. This part of the framework (effect assessment) has verified that the by changing the characteristics of a system, the effects change too. For the total travel time, is has been shown that this time can increase even though the in-vehicle travel time (speed) or the hidden waiting time (frequency) decrease. This is explained by the fact that people are willing to travel longer distances on the access and egress sides (catchment area increases). However, since (static) multipliers are used to determine the access and egress sides (based on the distances), the results can be slightly biased. It could be that for different types of services, the multipliers differ in value, hence stressing the need to research the differences in multipliers for different systems. Apart from the travel time, the changes in characteristics of the service saw an increase in the number of passengers (apart from the stop density alternative, which showed a decrease).

Conclusion and Recommendations

Q13: To what extent is the framework useful for performance assessment in practice?

Chapter 4 presented different issues that the framework needs to be able to assess:

- The influence of network specific characteristics on transport network integration;
- The influence of the integrated transport system on effects;
- The assessment and comparison of different system in terms of characteristics and effects.

In able to answer the sub-research question, whether or not these issues have been addressed needs to be determined.

1. The influence of network specific characteristics on transport network integration

The first step of the framework involved assessing the individual bus lines and comparing these lines to identify characteristics that influence network integration. This step proved to be successful: four relations have been identified that show a significant influence on integration. Furthermore, this step allowed to compare the bus systems not only on the line-level, bus also on the stop level.

2. The influence of the integrated transport system on effects

The second step of the framework involved determining if changes in characteristics of the system influence the system effects in the way that would expected. This is an extra step in validation the integration characteristics that have been found. After the initial assessment of the relations, this step ads certainty into the influence of these relations. Hence the second step of the framework ensures a double check to not only determine which characteristics influence integration, bus also determines the extent and effect of upgrading systems using these characteristics.

3. The assessment and comparison of different systems in terms of characteristics and effects

By assessing the different bus lines individually in the first part of the framework (bus line assessment), the framework allows for the comparison of different types of bus systems. As has been presented in chapter XX, the comparison of bus lines can first be made from a more general level of detail, where the bus lines that are of the same type are compared to bus lines of another type. Hence, the framework allows for identifying differences in characteristics (e.g. catchment area, modal choice) between different types of bus systems.

Conclusion

The incorporation of these three different aspects in the assessment framework results in a method that can be used to assess and compare different bus lines based on their performance. With the framework, integration can be assessed, both by the analysis of different characteristics of the different bus lines, as well as by the comparison of different bus lines belonging to different types of bus services (e.g. conventional lines and high quality lines). Furthermore, the framework allows to go even deeper into the understanding of integration, by not only analysing characteristics responsible for integration, but by also assessing the effects of altering these characteristics to allow for improved integration in the entire trip chain. As such, the framework is capable of assessing and identifying characteristics responsible for integration, as well as assessing the effects of the transport system. Apart from these scientific contribution of the framework, the framework is also useful for concession authorities and public transport operators to help assess the performance of their bus system, and to help indicate which characteristics could be improved in order to create a positive CBA outcome that benefits both the concession authority as well as the passenger.

8.2 Answer to the Research Question

With the previously stated conclusions, the research question can be answered. The research question has been developed and presented in chapter 1.

What are the main characteristics of the transport system and its environment that influence transport network integration, how do these characteristics relate to differences between conventional bus systems and high quality bus systems, and how can these characteristics be captured in a framework that assesses integration effects of the entire transport chain?

This research question is answered in three different steps. The first of the research question, *'What are the main characteristics of the transport system and its environment that influence transport network integration'* has been answered in chapter 6. This chapter identified two bus line characteristics, being commercial speed and frequency, and two environmental characteristics, being the spatial level around the stop and the typology (access of egress) of the stop, that influence the catchment area, and as such the integration of the system. With large qualitative competitive characteristics that drive the success of R-Net as a high quality bus service (speed, frequency), the catchment area of a stop is positively influenced: the competitive advantage of the system as a result of these characteristics makes that people travel longer distances to a stop.

With that, the second part of the research question *'How do these characteristics relate to differences between conventional bus systems and high quality bus systems'* has been partially answered while answering the previous part of the questions. The catchment radius around high quality bus stops (R-Net) is much larger than that for conventional lines (Comfortnet), both for walking as well as for cycling access and egress links.

The final part of the research questions *'How can these characteristics be captured in a framework that assesses integration effects of the entire transport chain'* has been answered with the development of the framework in chapter 4, and the testing of the framework with a case study in chapter 5, 6 and 7. The different characteristics are captured in the framework in the means that the framework allows for the assessment of these characteristics. Hence, the framework provides insight in the way the characteristics influence integration, rather than vice versa. Furthermore, in the final part of the assessment framework, the effects of the transport system are assessed, resulting in an explanation how integration influences these effects. As such, this framework is able to capture both the scientific relevance, as well as the societal relevance that have been expressed in chapter 1. With the framework, insight is given into the causes and effects of transport network integration (scientific relevance) and into the differences in performance between different types of bus systems (societal relevance). With that, the research objective has been met, and '*an assessment framework has been developed with which characteristics of the transport system that influence transport network integration can be distinguished, through the assessment of the performance of different types of bus services and their NMT access and egress modalities'*.

8.3 Recommendations

Apart for conclusions, this research has found several recommendations that should be taken into account for future purpose. The recommendations are split into three different categories: recommendations for the future use of the framework and the results of this research, recommendations for scientific public transport research, and recommendation for Stadsregio Amsterdam.

8.3.1 Recommendations for the Future use of the Assessment Framework and Results of this Research.

The first step of the framework can be used to assess the characteristics and determine the way they influence transport network integration. However, as has already been discussed in chapter 6, more data is needed be able to really determine if these relations hold for more observations. Furthermore, relations that have not shown a significant value in this research, could be significant when more observations are considered. Hence, the framework can be used to research integration aspects and characteristics of the system. However, to really say something about an integration factor, a large data base is needed to be able to fully compare lines with enough significant values.

Furthermore, the list of characteristics of the system that have been assessed was limited. This list could be extend further. For instance by including headway reliability (to determine the influence of 'bunching' on integration), as well as choice specific characteristics (comfort). However, this asks for a new approach. With the assessment method (framework) it can be tested how and to which extend certain parameters influence integration. Repeating this framework for a long list of characteristics with an extensive database (which allows for line comparison as well as for more in-depth stop comparison), can eventually result in a list of parameters influencing integration. This could eventually evolve into a common way to assess integration, an estimation for integration, where parameters and attributes are determined via parameter estimation methods, e.g. through the use of biogeme.

To summarize, future research could involve:

- The development of a data base of bus systems with their characteristics, which allows for the comparison of systems, as well as for the comparison of a system with its past performance, e.g. to observe differences after alterations in the system have been made.
- With an internally large sample of the population (through surveys) that have a low margin of error and allow for identifying relations with integration
- The assessment of the data in the data base to develop an integration estimator that assigns a value to a system for the level of integration.

Hence, this framework can be used to assess possible characteristics of the entire system that influence integration, identify and filter these characteristics, and eventually develop a model that specifies an 'integration estimator'.

8.3.2 Advice for Scientific Public Transport Research

Chapter 6 has presented two different characteristics of the bus system that have proven to be significant and that can determine integration. These two characteristics are the speed of the service and the frequency of the service. Furthermore, two spatial characteristics, the level of urbanisation and the typology of the bus stop, have proven to influence integration as well. The first recommendation for scientific research is to repeat the experiment for other bus lines, to determine if a large sample size can help in the explanation of relationships that influence integration. With a large database, characteristics that have now proven to be insignificant, and characteristics that have not been assessed in this research (e.g. service reliability, or more qualitative aspects of quality of service and information), can be researched.

The second recommendation for scientific research follows from the outcomes of chapter 7, which assessed the effects of transport network integration. As chapter 7 explained, the travel time is heavily influenced by the larger accepted catchment area and the used multiplier in the total travel time calculations. This step has proven that the identified characteristics do influence the effects of the transport system. Hence, it can be concluded that altering characteristic to increase integration positively influence the number of passengers and the total in-vehicle time. However, due to the use of multiplier, the total travel time has not decreased in al situations. Apparently, there are other aspects that could explain why people would accept longer distances (and thus times) on the access and egress sides of the trip when the performance of the bus link is enhanced. This has to be researched, to be able to change current assessment methods that only focus on one link of the transport chain. Assessing the entire chain, including total travel time, multipliers and the personal explanations into why people accept larger distances in the access and egress sides of the trips when the bus link characteristics are positively altered, are of utmost importance in both scientific research as well as operational planning of public transport systems.

8.3.3 Advice for Stadsregio Amsterdam for Concession Area Amstelland-Meerlanden

As the framework has been tested using a case study, several conclusions of this research are specifically aimed for the improvement of the bus lines assessed. Hence, these conclusions give insight in how to better integrate the different bus services of Amstelland-Meerlanden with NMT access and egress modalities.

First of all, the assessment of the modal shares for both R-Net and Comfortnet have shown that it could be beneficial to target passengers that use the bike on either the access side or the egress side. By providing parking facilities for bikes on the access side, the share of bike trips to the bus stop could increase. Especially when this means people use the bike instead of the bus for (short distance) first mile transport for distances that are too large to be covered by foot. On the egress side, the potential of the bike could be increased by offering alternatives for walking (longer distances) or using the bus for last-mile transportation. As has been shown, the share of the bike smaller on the egress side, due to the lack of availability of modalities. Introducing cycle-share options for important egress stops (as identified in chapter 6), could improve the position of the bike as a modality for egress transportation, and increase the flexibility of the egress trip. These options are especially important for R-Net bus services: bike shares a higher than for conventional bus services. This could be explained by the larges catchment area for R-Net services and the lower stop density, implying distances travelled to the bus stops are larger.

Secondly, the development of alternatives of bus lines have shown that passenger number and societal benefits (through a CBA-analysis) can be increased by altering the bus services or providing different infrastructural options. For a Comfortnet lines that has been assessed (line 172), the 'Ver-R-Netten' (upgrading of the service) is especially beneficial when the frequency of the service is increased. For line 172, the frequency alternative is most positive. No large investments, apart from stop refurbishments has to be made, while the number of passengers and as such the income from operations increases. However, the passenger benefits for this alternative are negative: this is explained by the use of total travel time rather than just the in-vehicle travel time. As the total travel time is influenced by an increase in catchment area, the travel time gains become negative. As such, it is important to further research the influence of the use of total travel time, including acceptance of longer access and egress times when in-vehicle times are shorter (speed alternative) of hidden waiting times are diminished (frequency alternative), as outcomes are now rather skewed.

For line 300, both alternative are positive, although the express alternative shows a much higher benefit outcome of 491 million euros. Table 28 showed that the number of passenger decreases for this alternative. However, as presented in Table 32, the travel time gains are tremendous for this alternative. Hence, the decrease in the number of passengers (and as such the operational income) is compensated by the positive travel time gains of the existing passengers. The already optimised version of line 300 hence does not imply further improvement of the line are impossible. A tunnel under the city centre of Haarlem both increases the speed of the service, it also attacks more passengers. And although the addition of an express service on the 300 route does not increase the number of passengers, the benefits outweigh the costs tremendously.

Finally, this research has given insight into a large amount of performance characteristics of the 10 bus lines of Amstelland-Meerlanden. These assessments have been presented in appendix G, and have been discussed in chapter 6. Construction of a Stadsregio Amsterdam Bus Line Performance Database, where this data, as well as future performance analyses of bus lines are stored, can help in the planning process of projects of Stadsregio Amsterdam. With the database, insight can be given into the individual performance of the bus lines, which helps in addressing performance issues and upgrading or improving the services. Furthermore, this database can give insight in the comparison of different bus lines based on performance and effects, which helps in the understanding of the differences between Comfortnet lines and R-Net lines. Finally, a database proves a way to assess changes in bus lines over time (e.g. after upgrading or after smaller alterations to the system), which allows for the identification of integration effects and performance effects, and can be useful in the decision making of large projects.

References

Abrantes, P., & Wardman, M. (2011). Meta-Analysis of UK values of Travel Time: An Update. *Transportation Research Part A*(45), 1-17.

Annema, J. (2009). Transport Resistance Factors: Time, Money and Effort. In B. van Wee, J. Annema, & D. Banister, *The Transport System and Transport Policy* (pp. 125-124). Cheltenham, United Kingdom: Edward Elgar Publishing Limitefd.

Annema, J., van den Brink, R., & Walta, L. (2009). Transport Technology to Reduce Transport's Negative Impacts. In J. A. Bert van Wee, *The Transport System and Transport Policy* (pp. 163-206). Cheltenham, United Kingdom: Edward Elgar Publishing Limited.

Bakker, P., Koopmans, C., & Nijkamp, P. (2010). Appraisal of Integrated Transport Policies. In M. Givoni, & D. Banister, *Integrated Transport - From Policy to Practice* (pp. 117-136). Oxford: Routeledge.

Bovy, P., & Jansen, G. (1979). Travel times for disaggregate travel demand moddeling: a discussion and a new travel time model. In G. Jansen, & et al., *New Developments in Modelling Travel Demand and Urban Systems* (pp. 129-158). England: Saxon House.

Bovy, P., Van der Waard, J., & Baanders, A. (1991). Substitution of travel demand between car and public transport: a discussion of possibilities. *Proceedings of PTRC seminar* (pp. 43-54). PTRC ed.

Brown, J., & Thompson, G. (2009). Express Bus Versus Rail Transit: How a Marriage of Mode and Mission Affects Transit Performance. *Transportation Research Record*(2110), 45-54.

CBS. (2014). *Demografische Kerncijfers per Gemeente.* Den Haag: CBS.

CBS. (2015). *Begrippen*. Retrieved May 3, 2015, from Centraal Burea voor de Statistiek: http://www.cbs.nl/nl-NL/menu/methoden/begrippen/default.htm?ConceptID=658

Cervero, R., Sarmiento, O., Jacoby, E., Gomez, L., & Neiman, A. (2009). Influences of built environments on walking and cycling: lessongs from Bogota. *International Journal of Sustainable Transportation*(3), 203-226.

Connexxion. (2015, May). *Dienstregeling*. Retrieved from Connexxion: www.connexxion.nl/dienstregeling

Covero, R., & Dai, D. (2014). BRT TOD: Leveraging Transit Oriented Development with Bus Rapid Transit Investments. *Transport Policy*(36), 127-138.

Currie, G., & Delbosc, A. (2011). Understanding Bus Rapid TRansit Route Ridership Drivers: An Emperical Study ofAutralian BRT Systems. *Transport Policy*(18), 755-764.

D.A., H., & Golob, T. (2008). Bus Rapid Transit Systems - A Comparative Assessment. *Transportation*(35 (4)), 501-518.

Deng, T., & Nelson, J. (2011). Recent Developments in Bus Rapid Transit: a Review of the Litarature. *Transport Reviews, Vol. 31 No.1* (Routeledge).

Department of Economic and Social Affairs. (2014 revision). *World Urbanization Prospects.* United Nations.

Eigenraam, C., Koopmans, C., Tang, P., & Werster, A. (2000). *Evaluatie van grote infrastructuurprojecten, leidraad voor Kosten-batenanalyse.* Den Haag: Ministerie van Verkeer en Vervoer, Ministerie van Economische Zaken.

EMTA. (2012, January 26). *Amsterdam : Identification of metropolitan area*. Retrieved February 5, 2015, from European Metropolitan Transport Authorities: http://www.emta.com/spip.php?article12&lang=en

EMTA. (2012). *EMTA barometer.* Paris: EMTA.

EMTA. (2013). *EMTA Barometer.* Paris: EMTA.

Ewing, R., & Cervero, R. (2001). Travel and the Built Environment: a Synthesis. *Transport Research Record*(1780), 1-3515.

Givoni, M., & Banister, D. (2010). *Integrated Transport - From Policy to Practice.* Oxford: Routledge.

Guequirre, N. (2003). *Demographics and Transportation in the United States 2050.* Milwaukee: University of Wisconsin.

Hensher, D. (2007). Sustainable public transport systems: moving towards a value for money and network-based approach and aay from blind commitment. *Transport Policy*(14(1)), 98-102.

Hensher, D., & Golob, T. (2008). Bus Rapid Transit Systems - a comparative assessment. *Transportation, 35 (4)*, 501-518.

Hensher, D., & Mulley, C. (2014). Modal Image: Candidate Drivers of Preference Differences for BRT and LRT. *Transportation*, 1-17.

Hickman, R., Seaborn, C., Headicar, P., & Banister, D. (2010). Planning for Suistanable Travel - Integration spatial planning and transport. In M. Givoni, & D. Banister, *Integrated Transport - From Policy to Practice* (pp. 33-53). Oxford: Routeledge.

Hodgson, P., Potter, S., Warren, J., & Gillingwater, D. (2013). Can Bus Really Be the New Tram? *Research in Transportation Economics*(39(1)), 158-166.

Hoogendoorn-Lanser, S. (2005). *Modelling Travel Behaviour in Multi-Modal Networks.* Delft: Technische Universiteit Delft.

Ibrahim, M. F. (2003). Improvements and integration of a public transport system: the case of Singapore. *Cities 20.3*, 205-216.

Janic, M. (2014). *Advanced Transport Systems - Analysis, Modeling, and Evaluation of Performances.* London: Springer.

Kager, R. (2015, February 23). Interview. (J. Brand, Interviewer)

Kennisinstituut voor Mobiliteitsbeleid. (2014). *Mobilitietsbeeld 2014.* Den Haag: Kennisinstituut voor Mobiliteitsbeleid.

Krizek, K. J., & Stonebraker, E. W. (2010). Bicycling and Transit - A marriage Unrealized. *Transportation Research Record: Journol of the Transportation Research Board*(2144), 161-167.

Krygsman, S., Dijst, M., & Arentze, T. (2004). Multimodal public transport: an analysis of travel time elements and the interconnectivity ratio. *Transport Policy*(11), 264-275.

Levinson, H., Zimmermann, S., Clinger, J., & Scott Rutherford, C. (2002). Bus Rapid Transit: an Overview. *Journal of Public Transportation*(Vol.5 No. 2).

Loutzenheiser, D. (1997). Pedestrian access to transit: model of walk trips and their design and urgan form determinants around bay area rapid transit stations. *Transportation Research Record*(1604).

Maat, C. (2010). Verstedelijking en Mobiliteit: de VS versus Nederland. Roermond: Colloquium Vervoersplanologisch Speurwerk.

Mackay, D. J. (2011). Sustainable Energy. Cambridge: UIT Cambridge Ltd.

McDonnel, S., & Zellner, M. (2011). Exploring the effectiveness of bus rapid transit a prototype agent-based model of commuting behaviour. *Transport Policy*(18), 825-835.

Muizelaar, T. (2011). *Non-recurrent traffic situations and traffic information. Determining preferences and effects on route choice.* Enschede, the Netherlands: TRAIL Research School.

NEA, OGM, & TSU. (2003). *Integration and Regulatory Structures in Public Transport.* Brussels: DGTREN.

Open OV. (2015, 04 12). *Open data*. Retrieved from Open OV: http://openov.nl/

Organisatie voor Economische Samenwerking en Ontwikkeling. (2007). *Territorial REviews: Randstad Holland.* Paris: Organisatie voor Economische Samenwerking en Ontwikkeling.

Postcode Data. (2015, 04 21). *Download*. Retrieved from Postcode Data - Postcode informatie van Nederland: http://www.postcodedata.nl/download/

Potter, S., & Skinner, M. (2000). On Transport Integration: A Contribution to Better Understanding. *Futures*(32), 275-287.

Preston, J. (2010). Measuring the Costs and Benefits of Integrated Transport Policies and Schemes. In M. Givoni, & D. Banister, *Integrated Transport - From Policy to Practice* (pp. 208-222). Oxford: Routeledge.

Provincie Noord-Holland. (2015). *Regio Amstelland-Meerlanden*. Retrieved March 11, 2015, from Provincie Noord-Holland: http://www.noord-holland.nl/web/bestuur/Gemeenten-1/Bestuurskracht/Regio-AmstellandMeerlanden.htm

Punzo, V., Torrieri, V., Borzachellio, M., Ciuffo, B., & Nijkamp, P. (2010). Assessing intermodal re-balance and integration in urban lagoon tube plan for Venice. In M. Givoni, & D. Banister, *Integrated Transport - From Policy to Practice* (pp. 257-273). Oxford: Routeledge.

Rietveld, P. (2000). Non-Motorized modes in transport systems: A multimodal chain perspective for the Netherlands. *Transportation Research Part D: Transport and Environment*(5), 31-36.

R-Net. (2015). *R-net in Noord-Holland/Flevoland*. Retrieved April 24, 2015, from R-Net: https://www.rnet.nl/noordholland-flevoland/waar-rijdt-r-net/

Romijn, G., & Renes, G. (2013). *Algemene Leidraad voor Maatschappelijke Kosten-Batenanalyse.* Den Haag: Planburea voor de Leefomgeving.

Rutten, N. (2010). *Benut bestaande stad en netwerk.* Grontmij.

Siedler, C. (2014). Can Bus Rapid Transit Be a Suitanable Means of Public Transport in Fast Growing Cities? Empircal Evidence in the case of Oslo. *Transportation Research Procedia*, 109-120.

Slebos, C. (2015, May 7). Stadsregio Amsterdam. (J. Brand, Interviewer)

Stadsregio Amsterdam. (2010). *R-net. Een productformule voor het Hoogwaardig Openbaar Vervoer.* Amsterdam: Stadsregio Amsterdam.

Stadsregio Amsterdam. (2013). *Investeringsagenda OV; Investeren in een bereikbare regio.* Amsterdam: Stadsregio Amsterdam.

Stadsregio Amsterdam. (2014). *English Information*. Retrieved January 2, 2015, from Stradsregio Amsterdam: http://www.stadsregioamsterdam.nl/algemene-onderdelen/english-information/#RegionalTrafficandTransportPlan

Stadsregio Amsterdam. (2014a). *Investeringsagenda Fiets 2015-2025.* Amsterdam: Stadsregio Amsterdam.

Stadsregio Amsterdam, Schiphol Group, Gemeente Amsterdam, & Strategy Development Partners. (2012). *Beter OV voor de Stadsregio Amsterdam; discussiedoment gericht op meer en beter OV met dezelfde middelen.* Amsterdam\: Stadsregio Amsterdam.

Struiksma, R., Tillema, T., & Arts, J. (2008). Space for mobility: towards a paradigm shift in Dutch transport infrastructure planning? *ACSP-AESOP Fourth Joint Congress*, (pp. 1-16).

Susilo, Y. O. (2010). Integrating Individual Travel Desires in Transport Planning. In M. Givoni, & D. Banister, *Integrated Transport - From Policy to Practice* (pp. 139-162). Oxford: Routeledge.

Tahmasseby , S. (2009). *Reliability in Urban Public Transport Network Assessment and Design.* Delft: Delft University of Technology.

Tyler, N. (2002). *Accessibility and the Bus System.* London: Thomas Telford Publishing.

Van Der Meulen, B. (2015, Mei 12). Stadsregio Amsterdam. (J. Brand, Interviewer)

Van Nes, R. (2002). *Design of Multimodal Transport Networks - A Hierarchical Approach.* Delft: Technische Universiteit Delft.

Van Oort, N. (2011). *Service Reliability and Urban Public Transport Design.* Delft: Delft University of Technology.

Van Oort, N., & Van Nes, R. (2009). Line length versus operational reliability: network design dilemma in urban public transportation. *Transportation research record*(No. 2112.), 104-110.

Veeke, H., Ottjes, J., & Lodewijks, G. (2011). *The Delft System Approach.* Delft: Springer-Verlag London Limited.

Vuchic, V. (2007). *Urban Transit - Systems and Technology.* Hoboken, New Jersey: John Wiley & Sons.

Wegener, M. (2004). Overview of Land-Use Transport Models. In D. A. Hensher, & K. Button, *Transport Geography and Spatial Systems* (pp. 127-146). Kidlington, UK: Pergamon/Elsevier.

Zamparini, L., & Reggiani, A. (2010). The Value of Reliability and its Relevance in Transport Networks. In M. Givoni, & D. Banister, *Integrated Transport - From Policy to Practice* (pp. 97-115). Oxford: Routeledge.

Zuidgeest, M., Brussel, M., Arora, A., Bhamidipati, S., Amer, S., De Souza, F., & Godefrooij, T. (2009). *Integratin Non-Motorized Transport to Public Transport.* SUMA.

Appendices

A. Concession Area Amstelland-Meerlanden

Table 36: Comfortnet bus lines in Amstelland-Meerlanden

Line	From	To	Note
142	Amsterdam Centrum	Wilnis	Snelbus
145	Amsterdam Centrum	Hoofddorp	
146	Amsterdam Zuid-Oost	Uithoorn	
149	Uithoorn	Amstelveen	
161	Zwanenburg	Hoofddorp	
162	Hoofddorp	Lisse	
163	Hoofddorp	Rijsenhout	
164	Hoofddorp	Sassenheim	
168	Hoofddorp Station	Hoofddorp Spaarne Ziekenhuis	Stadsdienst Hoofddorp
169	Schiphol-Rijk	Hoofddorp Spaarne Ziekenhuis	Stadsdienst Hoofddorp
170	Amsterdam Centraal	Uithoorn	
171	Aalsmeer	Amsterdam Zuid-Oost	
172	Amsterdam Centraal	Kudelstaart	
174	Amsterdam Centraal	Wilnis	If 142 does not operate
181	Schiphol-Zuid	Schiphol-Rijk	Schiphol Sternet
185	Schiphol Centrum	Schiphol Noord-West	Schiphol Sternet
186	Schiphol-Zuid	Amstelveen	Schiphol Sternet
187	Schiphol-Noord	Amstelveen	Schiphol Sternet
190	Schiphol-Noord	Schiphol-Zuid	Schiphol Sternet
191	Schiphol-Zuidoost	Schiphol-Noord	Schiphol Sternet
192	Schiphol-Zuid	Amsterdam Osdorp	Schiphol Sternet
193	Schiphol-Zuid	Schiphol-Oost	Schiphol Sternet
194	Schiphol-Zuid	Amsterdam Osdorp	Schiphol Sternet (rush-hour)
195	Schiphol-Zuid	Amsterdam Lelylaan	Schiphol Sternet
197	Schiphol-Zuid	Amsterdam Centrum	Schiphol Sternet
198	Schiphol-Noord	Aalsmeer	Schiphol Sternet
199	Schiphol-Zuid	Amsterdam Zuid-Oost	Schiphol Sternet
216	Schiphol-Oost	Almere Buiten	Rush-hour
241	Amsterdam Zuid	Amstelveen	Rush-hour
242	Amsterdam-Zuid	Wilnis	Rush-hour
261	Zwanenburg	Hoofddorp	Rush-hour, one direction
263	Hoofddorp	Rijsenhout	Rush-hour
268	Hoofddorp Station	Hoofddorp Spaarne Ziekenhuis	Stadsdienst Hoofddorp (Rush-hour)
272	Kudelstraat	Amsterdam Centraal	Rush-hour, one direction
275	Amsterdam Zuid-Oost	Flora Holland	Rush-hour, one direction
287	Schiphol-Centrum	Schiphol-Rijk	Rush-hour
401	Hoofddorp	Bennebriek	Buurtbus
487	Amstelveen Busstation	Kronenburg	
612	Abcoude	Amstelveen	School bus
622	Lijnden	Amstelveen	School bus
N70	Amsterdam Centraal	Wilnis	Night bus
N71	Amsterdam Centraal	Kudelstaart	Night bus
N97	Amsterdam Centrum	Schiphol-Zuid	Night bus

Table 37: R-Net lines in Amstelland-Meerlanden

Line	From	To	Note
300	Amsterdam Zuid-Oost	Haarlem	
310	Amsterdam Zuid	Nieuw Vennep	
340	Haarlem	Uithoorn	
346	Haarlem	Amsterdam Zuid	
356	Haarlem	Amsterdam Zuid-Oost	
N30	Haarlem	Amsterdam Zuid-Oost	Night Bus

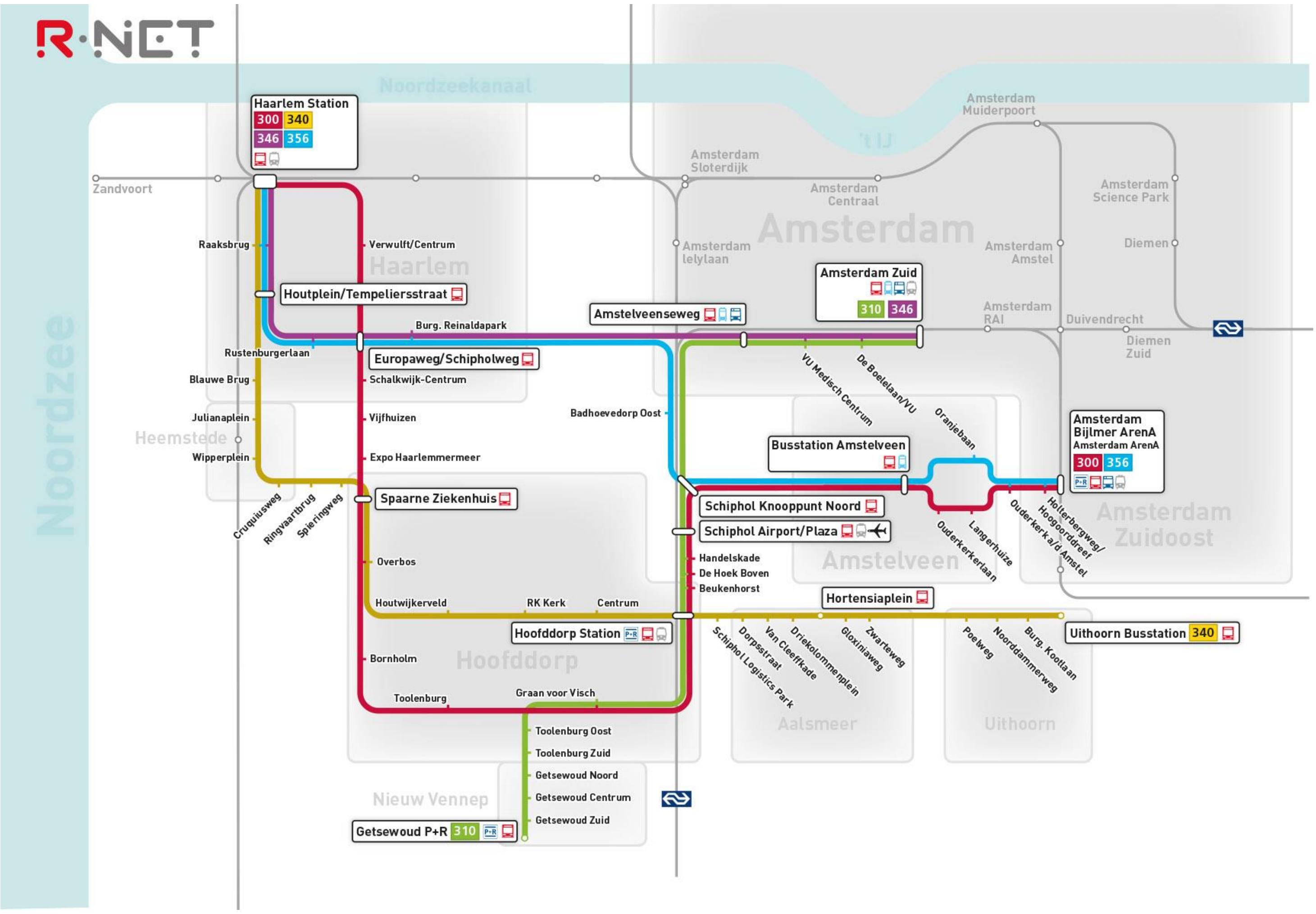


Figure 35: R-Net Lines in Amstelland-Meerlanden (R-Net, 2015)

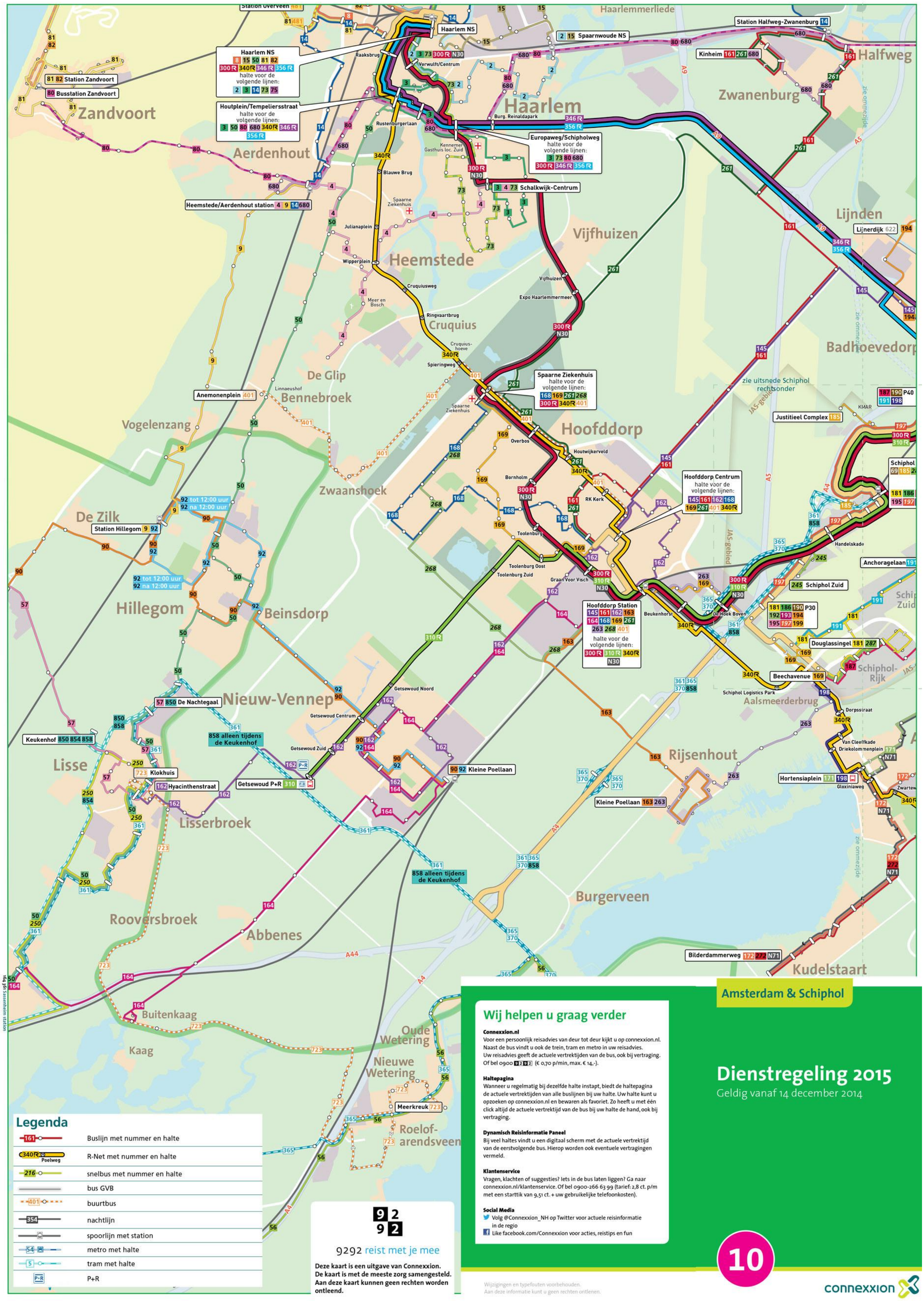


Figure 36: Bus lines in Amstelland-Meerlanden (part A)

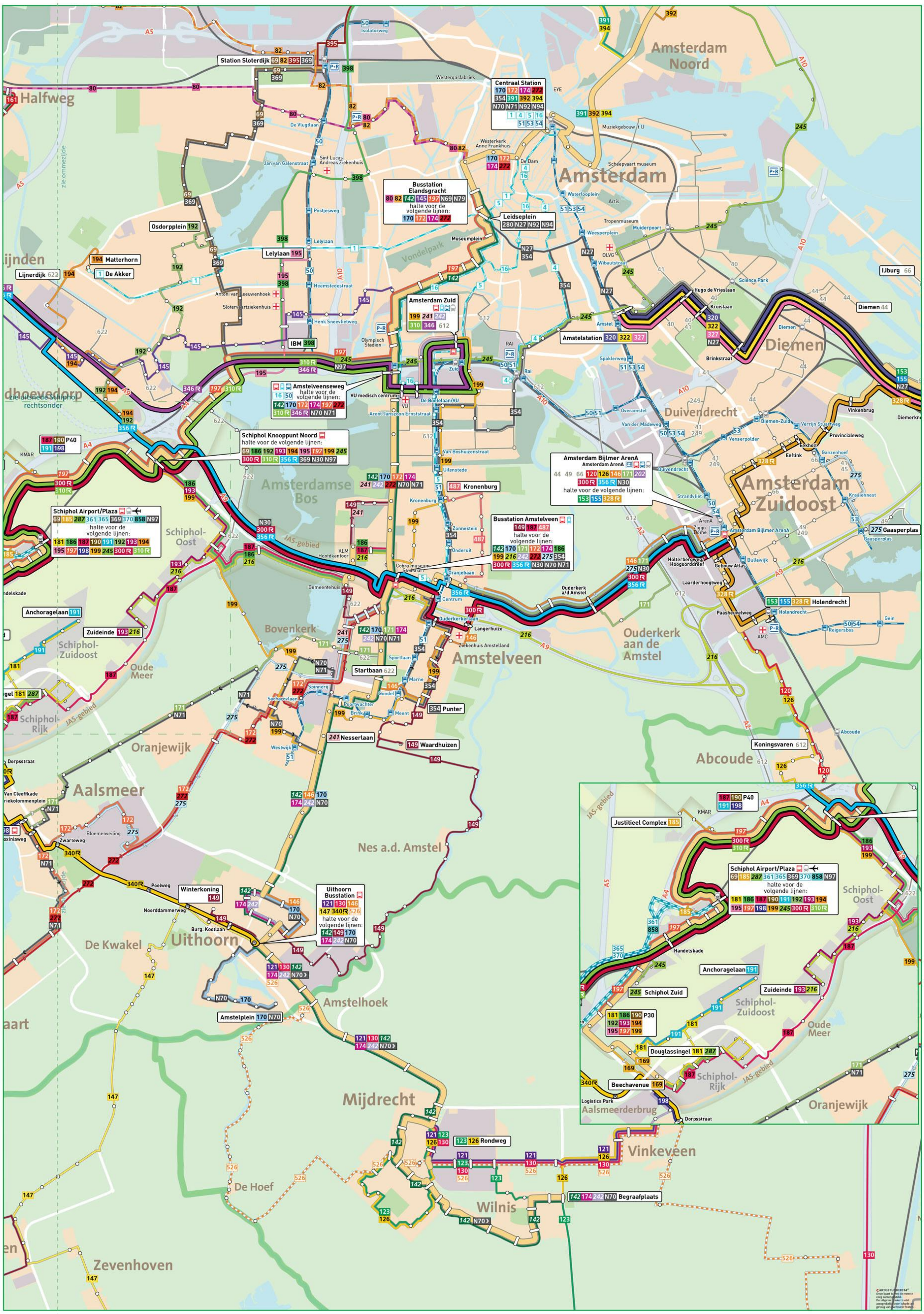


Figure 37: Bus lines in Amstelland-Meerlanden (part B)

B. Survey

The survey has been carried out on 5 Comfortnet bus lines, and 5 R-Net bus lines. All questions are the same for all lines, except for question 4 where the access and egress stop vary in accordance with the lines.

Geachte reiziger,

Connexxion en de Stadsregio Amsterdam proberen voortdurend de dienstverlening zo goed mogelijk op haar reizigers af te stemmen. Daarom stellen we het zeer op prijs als u deze vragenlijst invult. De gegevens worden volledig anoniem verwerkt. Het invullen van de vragenlijst duurt maximaal 4 minuten.
U kunt het ingevulde formulier bij het uitstappen weer inleveren bij één van de aanwezige enquêteurs van Moventem. Indien nodig, zijn de enquêteurs u graag behulpzaam bij het beantwoorden van eventuele vragen. De enquêteurs zijn te herkennen aan een witte Moventem jas en badges.
Wilt u hieronder de juiste antwoorden aankruisen of in blokletters invullen?

Hartelijk dank voor uw medewerking!

Stadsregio Amsterdam   connexxion

Moventem

Lijn 145

Datum

Ritnummer

Vertrektijd

1. Wat is de postcode van het adres waar u zojuist bent geweest?
Alleen de vier cijfers van de postcode zijn voldoende. Als u de postcode of straatnaam niet weet, graag de naam van het gebouw, school, bedrijf of organisatie vermelden.

Postcode:

Straat/ gebouw, school, bedrijf, organisatie:

Plaats:

2. Wat deed u op het adres van herkomst? *Eén antwoord mogelijk.*

- ❐ Wonen
- ❐ Werken
- ❐ Stage lopen
- ❐ Onderwijs volgen
- ❐ Winkelen
- ❐ Bezoek arts, tandarts of ziekenhuis
- ❐ Bezoek familie of vrienden
- ❐ Sporten/ recreatie
- ❐ Anders, namelijk

3. Hoe bent u naar de halte gekomen waar u in deze bus bent gestapt?
Het gaat alleen om het laatst gebruikte vervoermiddel voordat u in deze bus stapte. Eén antwoord mogelijk.

- ❐ Uitsluitend lopend
- ❐ Met de fiets
- ❐ Met de elektrische fiets
- ❐ Met de snorfiets/bromfiets/scooter
- ❐ Met de auto of motor
- ❐ Met de bus, lijnnummer:
- ❐ Met de tram, lijnnummer:
- ❐ Met de metro, lijnnummer:
- ❐ Met de trein, vanuit:
- ❐ Anders, namelijk

Z.O.Z

4. Kunt u onderstaand aankruisen bij welke halte u voor deze rit bent ingestapt en bij welke halte u weer gaat uitstappen?*(U kunt voor de haltenaam een kruis zetten voor de instaphalte en achter de haltenaam een kruis voor de uitstaphalte)*

Instap	Lijn 145		Uitstap	Instap	Lijn 145 (vervolg)		Uitstap
	Hoofddorp	Station			Amsterdam	Langsom	
	Hoofddorp	Nieuweweg			Amsterdam	Osdorperweg	
	Hoofddorp	Hoofddorp Centrum			Amsterdam	Ditlaar	
	Hoofddorp	Marktplein			Amsterdam	Sportpark Sloten	
	Hoofddorp	Kaj Munkweg			Amsterdam	Sloterweg 837	
	Hoofddorp	Oranjestraat			Amsterdam	Sloterweg 700	
	Hoofddorp	De Meerstede			Amsterdam	Armstrongstraat	
	Hoofddorp	Stationsweg			Amsterdam	Henk Sneevlietweg	
	Hoofddorp	Beemsterstraat			Amsterdam	Aletta Jacobslaan	
	Hoofddorp	Wijkermeerstraat			Amsterdam	Otho Heldringstraat	
	Hoofddorp	Cornelia's Hoeve			Amsterdam	Maassluisstraat	
	Hoofddorp	Vijfhuizerweg			Amsterdam	Naaldwijkstraat	
	Hoofddorp	Hoofdweg 271			Amsterdam	Aalsmeerplein	
	Hoofddorp	Hoofdweg 199			Amsterdam	Hoofddorpplein	
	Lijnden	Lijnden			Amsterdam	Zeilstraat	
	Badhoevedorp	Prins Mauritslaan			Amsterdam	Haarlemmermeerstation	
	Badhoevedorp	De Meerwende			Amsterdam	Amsterdam, C.Krusemanstraat	
	Badhoevedorp	Kamerlingh Onneslaan			Amsterdam	Valeriusplein	
	Badhoevedorp	Lorentzplein			Amsterdam	Emmastraat	
	Badhoevedorp	Havikstraat			Amsterdam	Jacob Obrechtstraat	
	Badhoevedorp	Spechtstraat			Amsterdam	Museumplein	
	Badhoevedorp	Rijstvogelstraat			Amsterdam	Rijksmuseum	
	Badhoevedorp	Uiverstraat			Amsterdam	Leidseplein	
	Badhoevedorp	Nieuwemeerdijk 69			Amsterdam	Busstation Elandsgracht	

5. Hoe lang duurt uw voortransport gemiddeld?
(Eén antwoord mogelijk)

- ❒ Minder dan 5 minuten
- ❒ Tussen 5 – 10 minuten
- ❒ Tussen 10 – 20 minuten
- ❒ Tussen 20 – 30 minuten
- ❒ Tussen 30 – 60 minuten
- ❒ Meer dan een uur

6. Wat is de belangrijkste reden dat u gebruik maakt van deze instaphalte?
(Eén antwoord mogelijk)

- ❒ Dan hoef ik minder vaak over te stappen
- ❒ Deze halte wordt vaak bedient (hoge frequentie bussen)
- ❒ De lijnen die deze halte aandoen brengen mij sneller op mijn bestemming
- ❒ Dichter bij mijn herkomstadres
- ❒ Deze halte is rustiger
- ❒ Deze halte ligt het beste op mijn reisroute
- ❒ Anders:

7. Hoe lang heeft u bij de instaphalte gewacht?

(Eén antwoord mogelijk)

- ❒ Minder dan 1 minuut
- ❒ Tussen 1 – 5 minuten
- ❒ Tussen 5 – 10 minuten
- ❒ Meer dan 10 minuten

8. Welke situatie is op uw reis van toepassing?

Eén antwoord mogelijk

- ❒ Ik ga deze reis vandaag ook in omgekeerde volgorde met de bus maken
- ❒ Ik heb deze reis vandaag ook in omgekeerde volgorde met de bus gemaakt
- ❒ Ik reis met een ander vervoermiddel heen/terug

9. Wat is de postcode van het adres waar u naar toe gaat?

Alleen de vier cijfers van de postcode zijn voldoende. Als je de postcode of straatnaam niet weet, graag de naam van het gebouw, school, bedrijf of organisatie vermelden.

Postcode:

Straat/ gebouw, school, bedrijf, organisatie:

Plaats:

10. Wat gaat u op dit adres doen?

Eén antwoord mogelijk.

- ❒ Wonen
- ❒ Werken
- ❒ Stage lopen
- ❒ Onderwijs volgen
- ❒ Winkelen
- ❒ Bezoek arts, tandarts of ziekenhuis
- ❒ Bezoek familie of vrienden
- ❒ Sporten/ recreatie
- ❒ Anders, namelijk

11. Met welk vervoermiddel reist u verder als u uit deze bus bent gestapt?

Het gaat alleen om het vervoermiddel dat u gebruikt direct nadat u uit deze bus stapt. Eén antwoord mogelijk.

- ❒ Uitsluitend lopend
- ❒ Met de fiets
- ❒ Met de elektrische fiets
- ❒ Met de snorfiets/bromfiets/scooter
- ❒ Met de auto of motor
- ❒ Met de bus, lijnnummer:
- ❒ Met de tram, lijnnummer:
- ❒ Met de metro, lijnnummer:
- ❒ Met de trein, vanuit:
- ❒ Anders, namelijk

Z.O.Z

12. Hoe lang duurt uw natransport gemiddeld?

(Eén antwoord mogelijk)

- ❒ Minder dan 5 minuten
- ❒ Tussen 5 – 10 minuten
- ❒ Tussen 10 – 20 minuten
- ❒ Tussen 20 – 30 minuten
- ❒ Tussen 30 – 60 minuten
- ❒ Meer dan een uur

13. Wat is de belangrijkste reden dat u gebruik maakt van deze uitstaphalte?

(Eén antwoord mogelijk)

- ❒ Dan hoef ik minder vaak over te stappen
- ❒ Deze halte wordt vaak bediend (hoge frequentie bussen)
- ❒ De lijnen die deze halte aandoen brengen mij sneller op mijn bestemming
- ❒ Dichter bij mijn herkomstadres
- ❒ Deze halte is rustiger
- ❒ Deze halte ligt het beste op mijn reisroute
- ❒ Anders:

14. Hoe vaak maakt u deze rit gemiddeld?

Hiermee wordt de rit in alleen deze richting bedoeld. Wanneer u op een ander moment vandaag in de andere richting reist, telt deze niet mee.

☐☐ dagen per

- ❒ Week
- ❒ Maand
- ❒ Jaar

15. Wat is uw geboortejaar ?

geboortejaar: ☐☐☐☐

16. Heeft u een beperking die uw keuze van reizen (ook in voor- en natransport) beïnvloed?

(Eén antwoord mogelijk)

- ❒ Nee
- ❒ Ja, een visuele beperking
- ❒ Ja, een motorische beperking
- ❒ Ja, een auditieve beperking
- ❒ Ja, anders namelijk

17. Kunt u toelichten hoe uw beperking uw keuze van transport beïnvloed?

Heeft u nog opmerkingen naar aanleiding van dit onderzoek?

Hartelijk dank voor uw medewerking aan dit onderzoek

C. Calculation of Travelled Distances

To be able to determine the catchment area of the bus stop, the distances travelled by passengers, as stated in the surveys, has to be calculated. This calculation consists of several steps.

Determining the Longitude and Latitude of Origins, Destinations and Stops

In the first step of calculations, the origins, destinations and bus stops are assigned longitude and latitude coordinates. This coordinates are derived from two data resources: Postal Code Data (Postcode Data, 2015) and bus stop coordinates (Open OV, 2015).

Determining the Distance between two Coordinates

The distance between two coordinates can be determined in two ways: via the road network, and via direct distances. The calculation of distances over the road network proves to be difficult: there are three sets of distances (access, bus, egress) for almost 700 trips. This needed number of distances is too large and too time consuming to determine using route length calculating websites (e.g. google maps). Furthermore, the information of these sites is often not accurate and can be out dated. For the easy of calculation, this research determines the distances based on the direct distance between two coordinates. This however causes over- and underestimation, which should be corrected (see appendix E and chapter 5).

The direct distances between two coordinates is calculated using an equations that determines the distances between two points on a sphere. As mentioned, three different distances are calculated, these are:

- The distance from the origin to the bus stop
- The distance from bus stop to bus stop
- The distance from the bus stop to the destination

Determining these destinations allows for the evaluation of validity of survey outcomes (see chapter 5).

The calculations have been made in an excel sheet. Hence the equations is an excel equation. The following equation is used to determine the distances between two points on a sphere:

$$Distance = ACOS(\sin(LAT_1) * \sin(LAT_2) + \cos(LAT_1) * \cos(LAT_2) * \cos(LONG_2 - LONG_1)) * 6371$$

$$\begin{aligned} &Where \\ &LAT_n = latitude\ of\ point\ n \\ &LONG_n = longitude\ of\ point\ n \\ &6371 = correction\ factor\ for\ metres \end{aligned}$$

D. Over- and Underestimation of Distances

As explained in appendix D and in chapter 5, the use of direct distances, combined with the use of 4PC data (lower level of detail), results in over- and underestimation of trips.

Figure 38 shows the consequences of an overestimation of distances. This is a representation of one of the access trips of a passenger that has completed a survey. The passenger leaves his origin at the Legmeerdijk in Amstelveen, and walks to bus stop Flora Holland Oost. However, the postal code of the origin has a centroid that is much further away from the bus stop. Hence, resulting in an overestimation of 1400 meters of the walked distance.

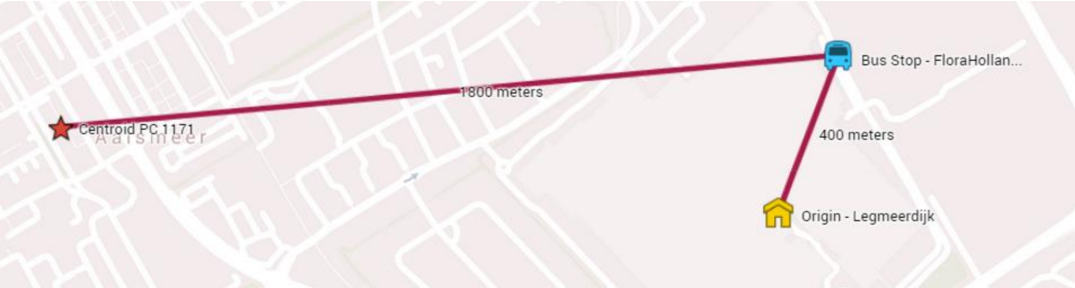


Figure 38: Overestimation of Distances

Figure 39 shows an underestimation for a bike access link. The passenger originates from the Eksterstraat in Badhoevedorp, and cycles to the Havikstraat bus stop. The centroid of postal code of the origin, 1171 only lies 40 metres from the bus stop, while the real distances travelled is 650 meters. Hence this results in an underestimation of the travelled distance of 610 meters.

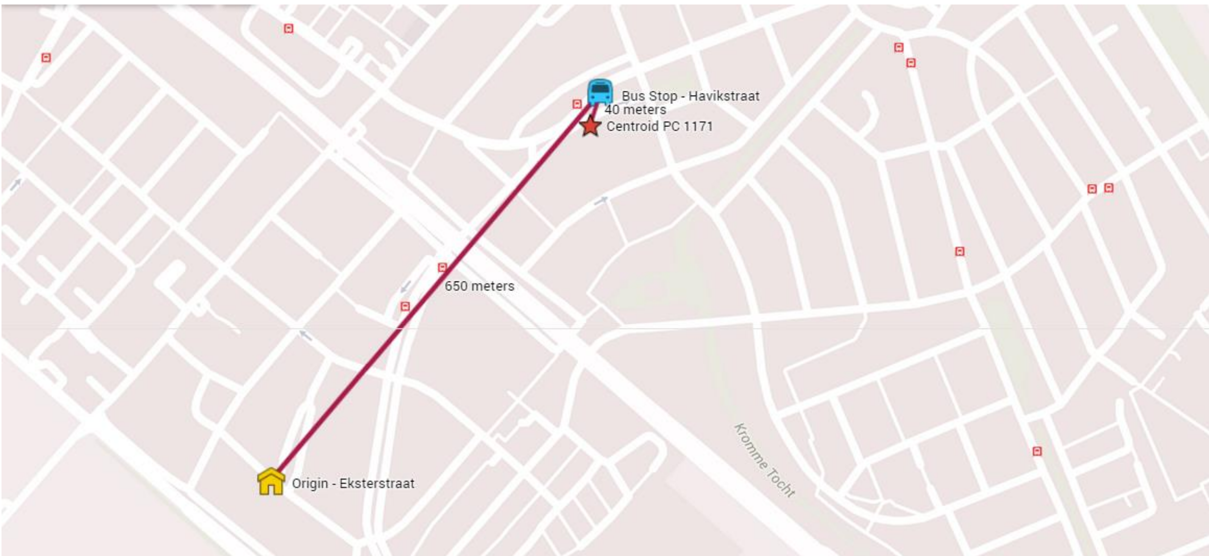


Figure 39: Underestimation of Distances

E. General Survey Outcomes

Survey Response

Table 38: Survey Response per Line

Line	Boardings	Survey Resonses	Usable Responses	Response (%)
145	119	77	71	60%
146	116	41	40	34%
162	64	36	35	55%
172	318	164	163	51%
187	42	16	16	38%
Total Comfortnet	**659**	**334**	**325**	**49%**
300	481	122	112	23%
310	149	83	80	54%
340	167	74	68	41%
346	135	99	96	71%
356	287	85	84	29%
Total R-Net	**1219**	**463**	**440**	**36%**

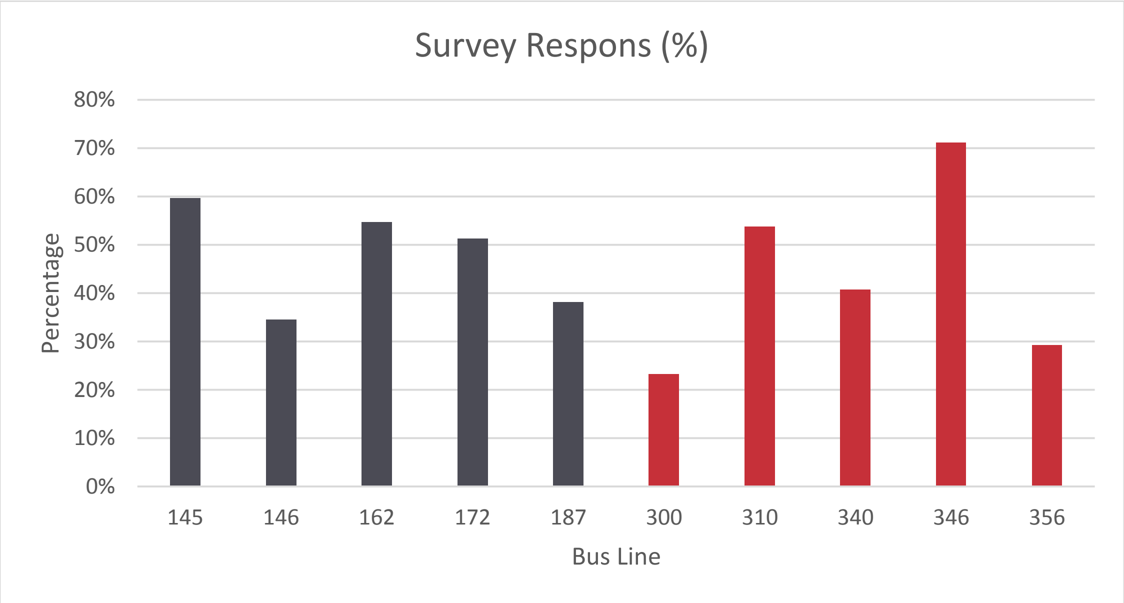


Figure 40: Visualisation of Survey Response

Margin of Error

Table 39: Statistic Information of Survey

	Comfortnet	R-Net
Total Population	260000	260000
Survey Response	334	463
Confidence Interval	95%	95%
Margin of Error	5,40%	4,60%

Response over Time

Table 40: Survey Response over Time

	145	146	162	172	187	300	310	340	346	356
Off-peak	13	30	0	52	6	37	23	17	37	48
Rush Hour	43	10	23	68	10	62	57	37	59	36
Evening	15	0	12	43	0	13	0	14	0	0
TOTAAL	71	40	35	163	16	112	80	68	96	84

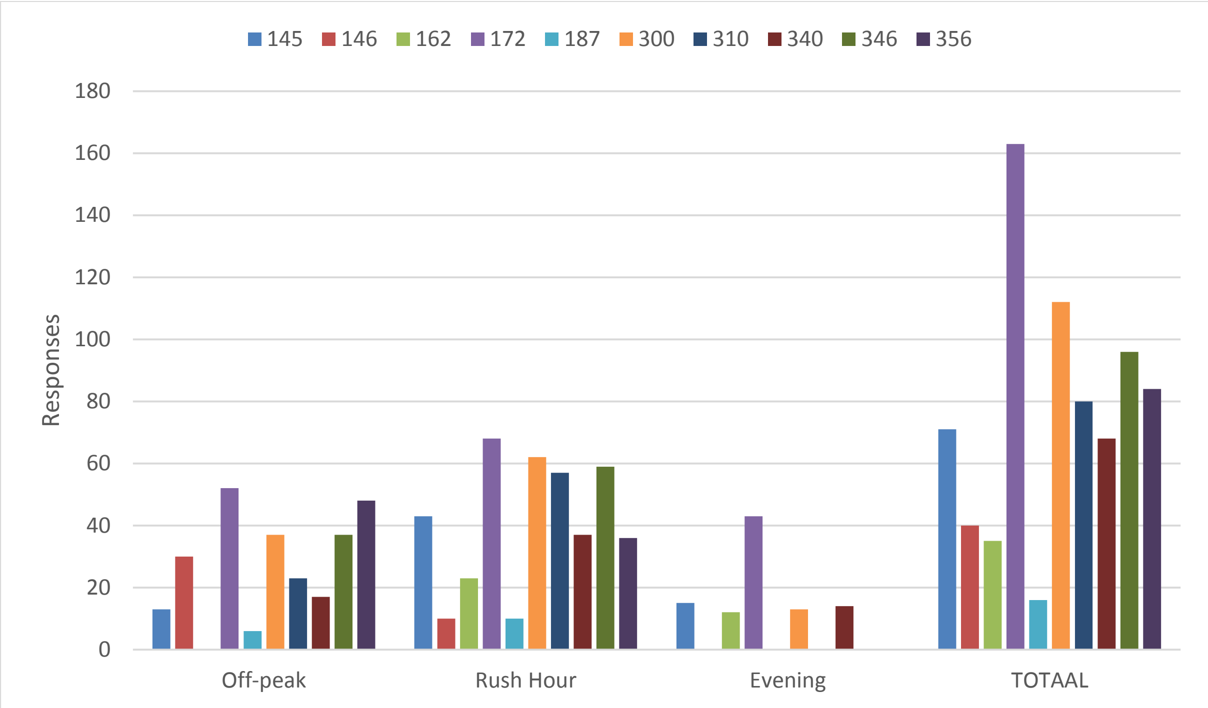


Figure 41: Survey Response over Time

Trip Frequency

Table 41: Trip Frequency

	146	146	162	172	187	300	310	340	346	356
Several times a year	1	1	1	11	0	4	3	6	6	4
About 1 time a month	2	2	2	19	0	7	3	2	7	3
About 1 time a week	3	3	4	23	1	9	14	4	5	5
2 to 3 times a week	8	8	4	26	1	20	15	16	15	13
3 to 4 times a week	0	0	0	0	0	0	1	0	0	0
4 to 5 times a week	12	12	12	47	13	58	40	30	51	48
More than 5 times a week	3	3	1	12	0	6	1	3	1	2
TOTAL	29	29	24	138	15	104	77	61	85	75

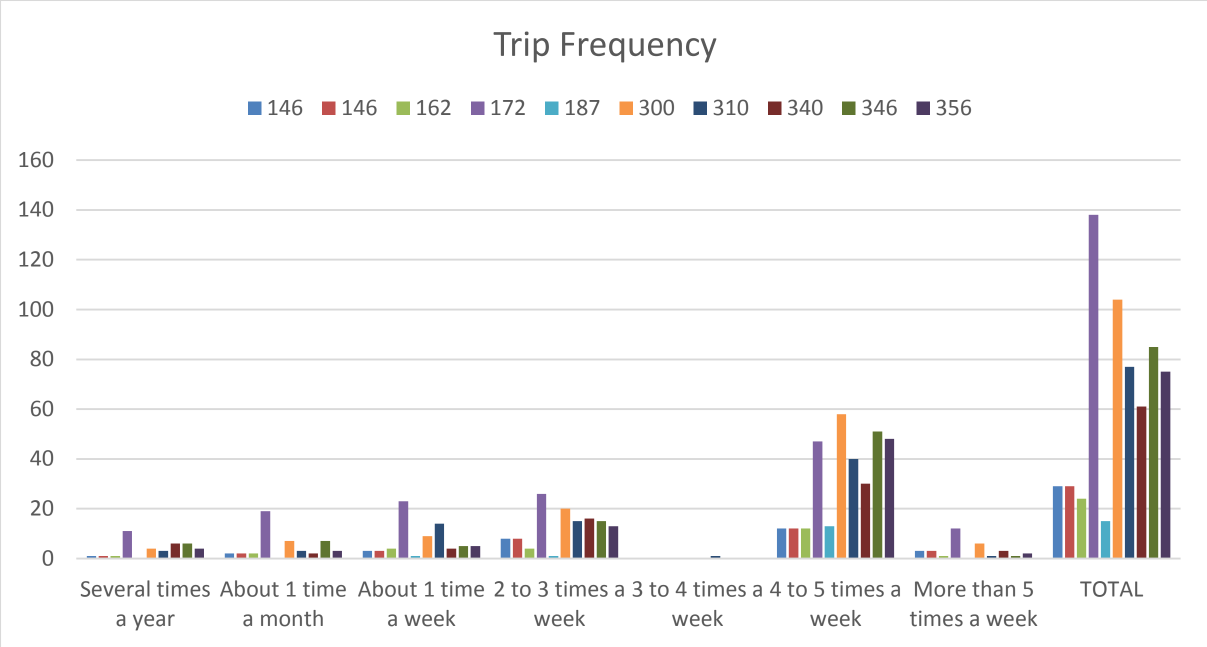


Figure 42: Trip Frequency

Travel Motive

Table 42: Travel Motive

	146	146	162	172	187	300	310	340	346	356
Work	9	9	9	53	15	57	31	23	43	39
Living	0	0	0	5	0	4	1	1	0	1
Education	13	13	4	21	1	13	24	13	26	26
Internship	2	2	2	6	0	8	2	7	2	3
Shopping	1	1	3	9	0	11	3	4	0	4
Doctor, dentist or hospital	6	6	0	6	0	0	3	1	6	0
Visting friends or family	3	3	9	18	0	7	5	10	6	2
Sport/leisure	0	0	2	10	0	2	2	3	1	0
Other	6	6	1	27	0	8	8	4	4	6
Unknown	0	0	5	8	0	2	1	2	8	3
TOTAAL	**40**	**40**	**35**	**163**	**16**	**112**	**80**	**68**	**96**	**84**

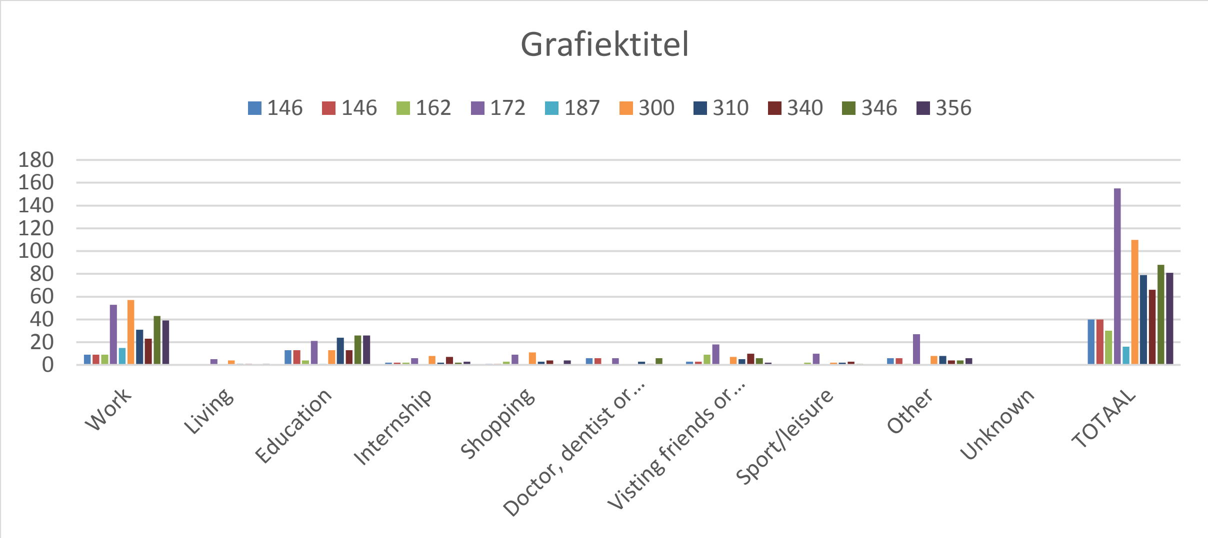


Figure 43: Travel Motive

Access and egress modalities

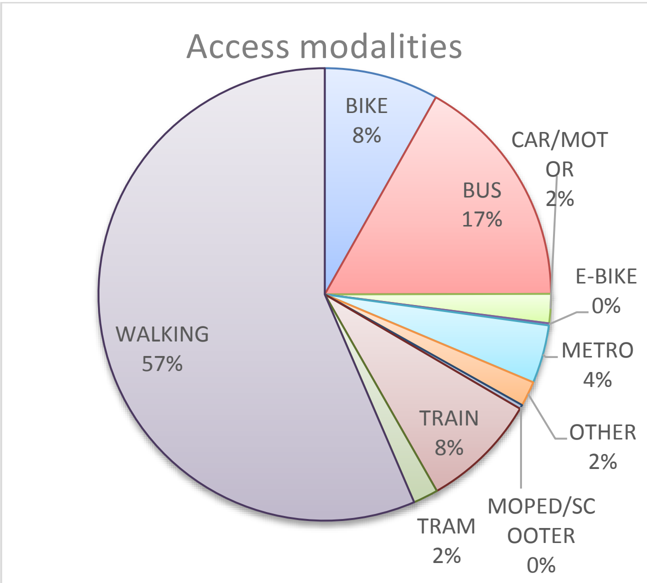


Figure 44: Access Modalities

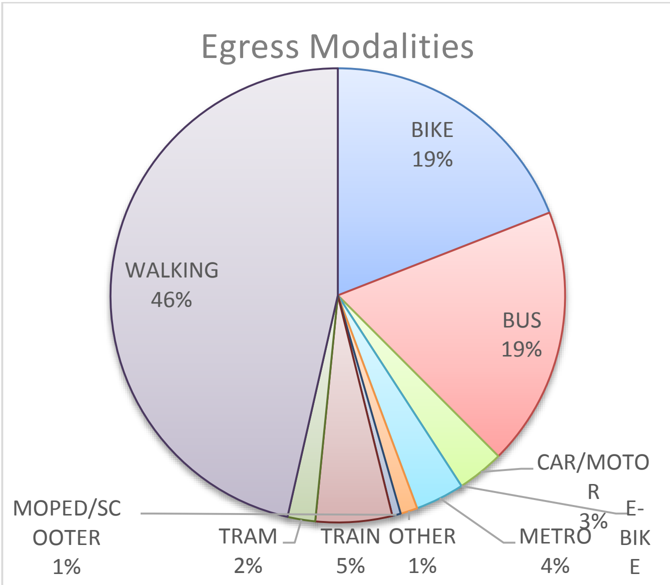


Figure 45: Egress Modalities

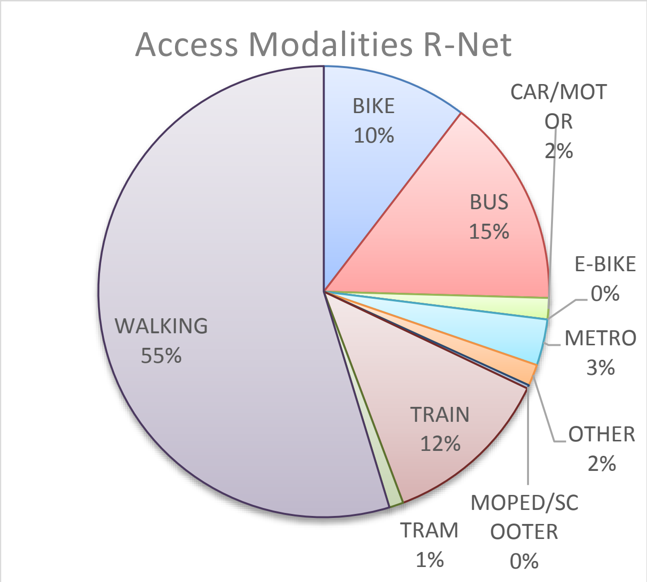


Figure 46: Access Modalities R-Net

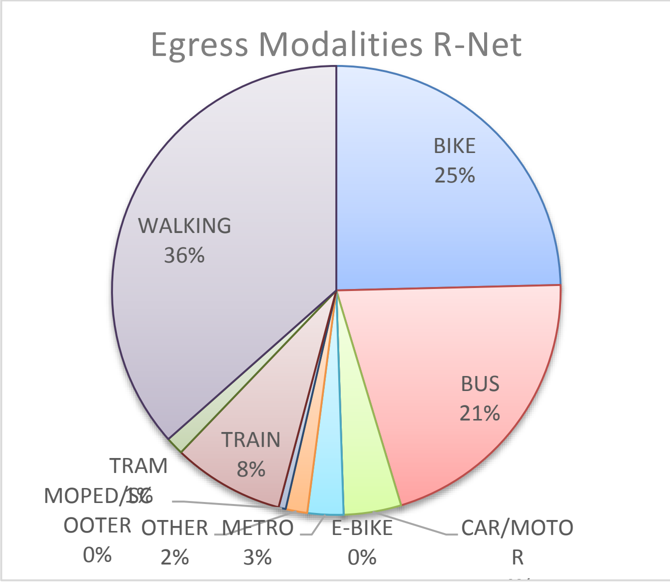


Figure 47: Egress Modalities R-Net

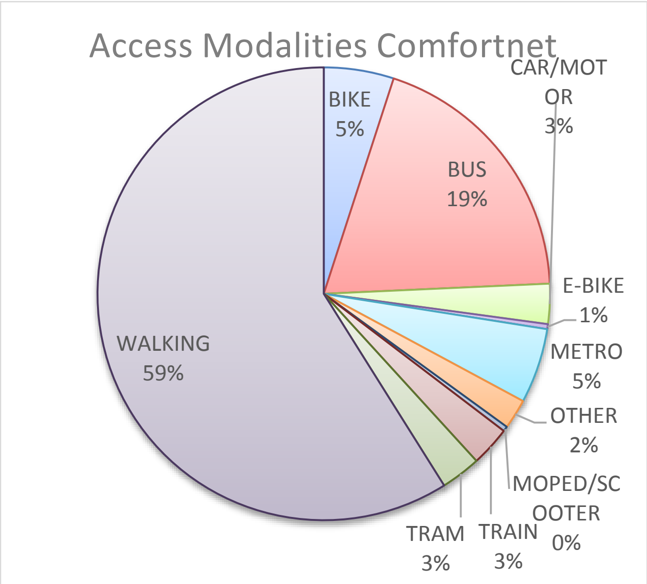


Figure 48: Access Modalities Comfortnet

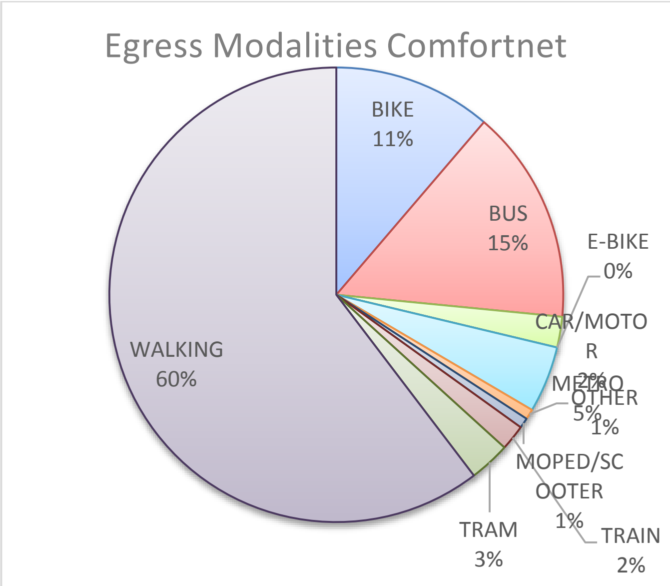


Figure 49: Egress Modalities Comfortnet

F. Assessment Method of Characteristics

Calculation of Travel Times

The travel times in the access and egress side of the trips have been calculated using a speed of 5 km/h for walking, and 20 km/h for cycling (Mackay, 2011).

Calculation of Stop Densities

Stop Densities have been determined using the equation:

$$Stop\ Density = \frac{\#number\ of\ stops}{line\ lenght}$$

Calculating Service Reliability

An important aspect that helps determine the reliability of a service is the punctuality. The punctuality determines if and to which extend the departure of a bus at a specific stop deviates from the scheduled departure. The punctuality can be measured using the following equation:

$$p_l = \frac{\sum_j^{n_{i,j}} \sum_i^{n_{i,j}} \left| D_{l,i,j}^{act} - D_{l,i,j}^{sched} \right|}{n_{l,j} * n_{l,i}}$$

$where$
$p_l = average\ punctuality\ on\ line\ l$
$D_{l,i,j}^{act} = actual\ departure\ time\ of\ vehicle\ i\ on\ stop\ j\ on\ line\ l$
$D_{l,i,j}^{sched} = scheduled\ departure\ time\ of\ vehicle\ i\ on\ stop\ j\ on\ line\ l$
$n_{l,j} = number\ of\ stops\ of\ line\ l$
$n_{l,i} = number\ of\ trips\ of\ line\ l$

One must take into account that this measure for punctuality does not state if a trip is too late or too early (Van Oort N. , 2011).

Stadsregio Amsterdam has specified three important constraint when considering if a bus is too late or too early. These are summarised in table XX. These allowed deviations are used to calculate the punctuality of the ten bus lines in appendix XX.

Table 43: Allowed Deviance from Timetable

Type of departure	Type of Stop	Allowed deviance (s)
Late departure	Departure stop	120
Late departure	Intermediate stop	180
Early departure	All stops	0

G. Bus Line Assessment

G.1 Comfortnet – Line 145

Bus line 145 is a 'Green' bus line in Amstelland-Meerlanden, and thus a Comfortnet line. The route of this bus line goes from Hoofddorp to Amsterdam. Figure 50 presents this route in the concession area Amstelland-Meerlanden.

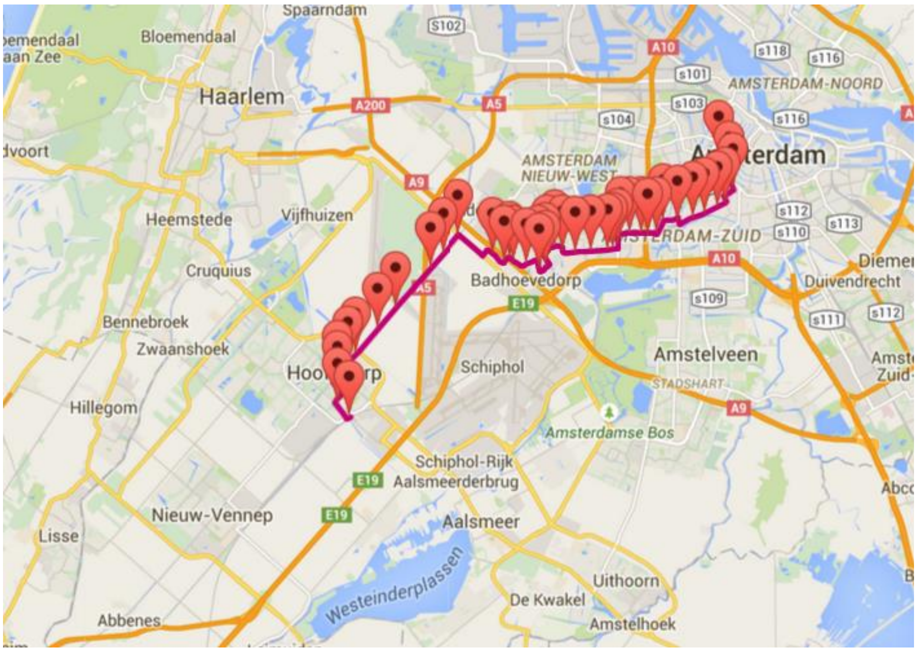


Figure 50: Route of Line 145 (Connexxion, 2015)

General Line Information

End Stop 1	Hoofddorp, Station
End Stop 2	Amsterdam, Busstation Elandsgracht
Frequency peak-hour (times/hour)	4
Frequency off-peak hour (times/hour)	2
Total number of stops (#)	43
Length (km)	22,490
Stop density (stops/km)	1,91
Average stop distance (km)	0,52
Dedicated infrastructure (km)	3,250
Dedicated infrastructure (% of total route)	15%
Number of bus trips (# in March)	2312
Number of passengers (#/week-day)	1950

Table 44: General Information of Line 145

Survey Information

Number of passengers (#/week-day)	1950
Number of usable survey responses	68
Confidence interval	95%
Margin of Error	11.68%

Table 45: Survey Information of Line 145

Access and Egress Modalities

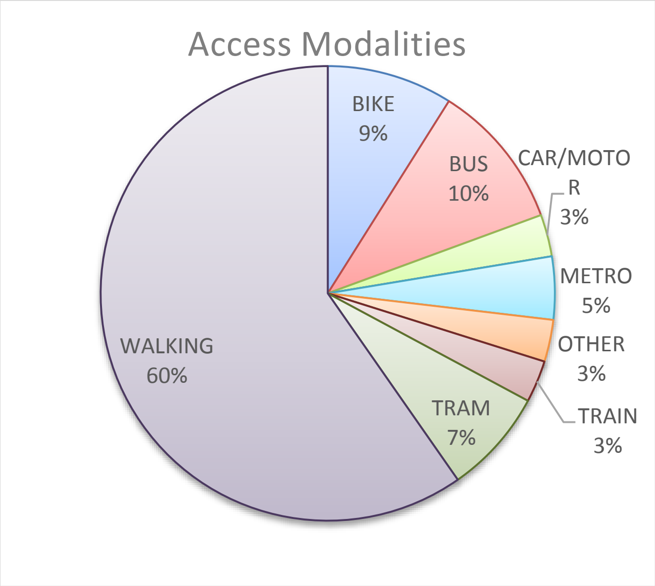


Figure 51: Access Modalities of Line 145

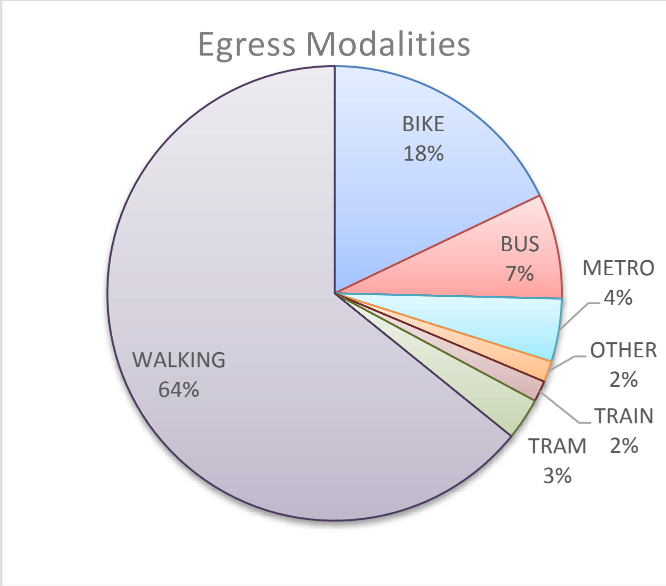


Figure 52: Egress Modalities of Line 145

Modality	Access	%	Egress	
BIKE	6	9%	12	18%
BUS	7	10%	5	7%
CAR/MOTOR	2	3%	0	0%
E-BIKE	0	0%	0	0%
METRO	3	4%	3	4%
OTHER	2	3%	1	1%
MOPED/SCOOTER	0	0%	0	0%
TRAIN	2	3%	1	1%
TRAM	5	7%	2	3%
WALKING	40	60%	43	64%
TOTAL	67	100%	67	100%

Table 46: Access and Egress Modalities for Line 145

Catchment Stop

Table 47: Catchment Area (distance in kilometres) of Bus Stops on Line 145

Access	MIN	P25	MED	P75	MAX
Bike	0,031	0,219	0,843	1,992	3,066
Walk	0,031	0,483	0,760	0,919	1,679
Egress	**MIN**	**P25**	**MED**	**P75**	**MAX**
Bike	0,0313	0,4064	0,6524	1,6235	3,9502
Walk	0,0313	0,4064	0,6524	0,9058	1,3498

Table 48: Catchment Area (travel time in minutes) of Bus Stops on Line 145

Access	Min	P25	MED	P75	MAX
Bike	0:00:06	0:00:39	0:02:32	0:05:59	0:09:12
Walk	0:00:23	0:05:48	0:09:07	0:11:01	0:20:09
Egress	**Min**	**P25**	**MED**	**P75**	**MAX**
Bike	0:00:06	0:01:13	0:01:57	0:04:52	0:11:51
Walk	0:00:23	0:04:53	0:07:50	0:10:52	0:16:12

Stop Performance

Stop Density

$$Stop\ Density = \frac{\#number\ of\ stops}{line\ lenght} = \frac{43}{22{,}490} = 1{,}91\ {}^{stops}/_{km}$$

Waiting time

Table 49: Waiting Times of Line 145

	Peak Hour	Off-Peak
Frequency (busses/hour)	4	2
Max Waiting time (minutes)	15	30

Classification of Stops

Stop		Number	# stops	% stop (usage)	postal code	Spatial	Activities	#access	#egress	% access	% egress	Stop type
Amsterdam, Busstation Elandsgracht	Amsterdam - Busstation Elandsgracht	1	1671	72%	1016	1	Residential	1	3	25%	75%	Egress
Amsterdam, Leidseplein	Amsterdam - Leidseplein	2	2074	90%	1017	1	Work/Education	5	8	38%	62%	Egress
Amsterdam, Rijksmuseum	Amsterdam - Rijksmuseum	3	575	25%	1071	1	Leisure/Shopping	2	0	100%	0%	Access
Amsterdam, Museumplein	Amsterdam - Museumplein	4	1779	77%	1071	1	Leisure/Shopping	5	6	45%	55%	Egress
Amsterdam, Jacob Obrechtstraat	Amsterdam - Jacob Obrechtstraat	5	517	22%	1071	1	Leisure/Shopping	0	1	0%	100%	Egress
Amsterdam, Emmastraat	Amsterdam - Emmastraat	6	633	27%	1071	1	Leisure/Shopping	0	0	0%	0%	Unclear
Amsterdam, Valeriusplein	Amsterdam - Valeriusplein	7	789	34%	1075	1	Mixed	1	1	50%	50%	Unclear
Amsterdam, C.Krusemanstraat	Amsterdam - C.Krusemanstraat	8	294	13%	1016	1	Residential	0	0	0%	0%	Unclear
Amsterdam, Zeilstraat	Amsterdam - Zeilstraat	9	459	20%	1016	1	Residential	0	0	0%	0%	Unclear
Amsterdam, Hoofddorpplein	Amsterdam - Hoofddorpplein	10	1265	55%	1059	1	Mixed	2	1	67%	33%	Access
Amsterdam, Aalsmeerplein	Amsterdam - Aalsmeerplein	11	818	35%	1186	2	Residential	0	0	0%	0%	Unclear
Amsterdam, Maassluisstraat	Amsterdam - Maassluisstraat	13	491	21%	1017	1	Work/Education	0	0	0%	0%	Unclear
Amsterdam, Naaldwijkstraat	Amsterdam - Naaldwijkstraat	12	747	32%	1071	1	Leisure/Shopping	0	0	0%	0%	Unclear
Amsterdam, Ottho Heldringstraat	Amsterdam - Ottho Heldringstraat	14	1709	74%	1059	1	Mixed	1	2	33%	67%	Egress
Amsterdam, Aletta Jacobslaan	Amsterdam - Aletta Jacobslaan	15	766	33%	1066	1	Mixed	4	2	67%	33%	Access
Amsterdam, Henk Sneevlietweg	Amsterdam - Henk Sneevlietweg	16	17	1%	1066	1	Mixed	6	0	100%	0%	Access
Amsterdam, Sloterweg 700	Amsterdam - Sloterweg 700	18	450	19%	1071	1	Leisure/Shopping	0	0	0%	0%	Unclear
Amsterdam, L. Armstrongstraat	Amsterdam - Armstrongstraat	17	1264	55%	1066	1	Mixed	1	2	33%	67%	Egress
Amsterdam, Sloterweg 837	Amsterdam - Sloterweg 837	19	458	20%	1066	1	Mixed	0	0	0%	0%	Unclear
Amsterdam, Sportpark Sloten	Amsterdam - Sportpark Sloten	20	433	19%	1066	1	Mixed	0	0	0%	0%	Unclear
Amsterdam, Ditlaar	Amsterdam - Ditlaar	21	542	23%	1082	1	Residential	0	0	0%	0%	Unclear
Amsterdam, Osdorperweg	Amsterdam - Osdorperweg	22	829	36%	1060	1	Residential	0	2	0%	100%	Egress
Amsterdam, Langsom	Amsterdam - Langsom	23	1294	56%	1171	3	Residential	1	4	20%	80%	Egress
Badhoevedorp, Nieuwemeerdijk 69	Badhoevedorp - Nieuwemeerdijk 69	24	54	2%	1171	3	Residential	0	0	0%	0%	Unclear
Badhoevedorp, Rijstvogelstraat	Badhoevedorp - Rijstvogelstraat	26	526	23%	1171	3	Residential	1	2	33%	67%	Egress
Badhoevedorp, Uiverstraat	Badhoevedorp - Uiverstraat	25	716	31%	1171	3	Residential	0	3	0%	100%	Egress
Badhoevedorp, Spechtstraat	Badhoevedorp - Spechtstraat	27	343	15%	1171	3	Residential	2	1	67%	33%	Access
Badhoevedorp, Havikstraat	Badhoevedorp - Havikstraat	28	1382	60%	1171	3	Residential	2	4	33%	67%	Egress
Badhoevedorp, Lorentzplein	Badhoevedorp - Lorentzplein	29	1683	73%	1171	3	Residential	2	9	18%	82%	Egress
Badhoevedorp, Kamerlingh Onneslaan	Badhoevedorp - Kamerlingh Onneslaan	30	1039	45%	1171	3	Residential	0	0	0%	0%	Unclear
Badhoevedorp, De Meerwende	Badhoevedorp - De Meerwende	31	639	28%	1171	3	Residential	2	1	67%	33%	Access
Badhoevedorp, Prins Mauritslaan	Badhoevedorp - Prins Mauritslaan	32	216	9%	1171	3	Residential	0	2	0%	100%	Egress
Lijnden, Lijnden	Lijnden - Lijnden	33	318	14%	1175	5	Work/Education	0	2	0%	100%	Egress
Hoofddorp, Hoofdweg 199	Hoofddorp - Hoofdweg 199	34	11	0%	2132	3	Work/Education	0	0	0%	0%	Unclear
Hoofddorp, Hoofdweg 271	Hoofddorp - Hoofdweg 271	35	44	2%	2132	3	Work/Education	0	0	0%	0%	Unclear
Hoofddorp, Vijfhuizerweg	Hoofddorp - Vijfhuizerweg	36	52	2%	2132	3	Work/Education	0	0	0%	0%	Unclear
Hoofddorp, Cornelia's Hoeve	Hoofddorp - Cornelia's Hoeve	37	103	4%	2132	3	Work/Education	0	0	0%	0%	Unclear
Hoofddorp, Wijkermeerstraat	Hoofddorp - Wijkermeerstraat	38	897	39%	2131	3	Residential	4	0	100%	0%	Access
Hoofddorp, Beemsterstraat	Hoofddorp - Beemsterstraat	39	1108	48%	2131	3	Residential	1	1	50%	50%	Unclear
Hoofddorp, Marktplein	Hoofddorp - Marktplein	40	1534	66%	2131	3	Residential	6	0	100%	0%	Access
Hoofddorp, Hoofddorp Centrum	Hoofddorp - Hoofddorp Centrum	41	2169	94%	2132	3	Work/Education	10	4	71%	29%	Access
Hoofddorp, Nieuweweg	Hoofddorp - Nieuweweg	42	752	33%	2132	3	Work/Education	1	3	25%	75%	Egress
Hoofddorp, Station	Hoofddorp - Station	43	1790	77%	2132	3	Work/Education	2	1	67%	33%	Access
TOTAAL			35250	35%						28%	35%	

Table 50: Classification of Stops of Line 145

Table 51: Stop Usage of Line 145

Average stop usage in March (%)		35%
Most used stop	Hoofddorp, Hoofddorp Centrum	95%
Least used stop	Hoofddorp, Hoofdweg 199	0%

Line Performance

Commercial Timetable Speed and In-vehicle time

Table 52: Commercial speed of Line 145

Length of line	22.490
Timetable A to B (h)	0.83
Commercial time table speed	27,10
In-vehicle time (min)	22

Trip Cancelations

Table 53: Trip Cancelations of Line 145

# trips	2312
# cancelled	2
% cancelled	0,1%

Punctuality

Table 54: Average deviation from punctuality for all trips on line 145

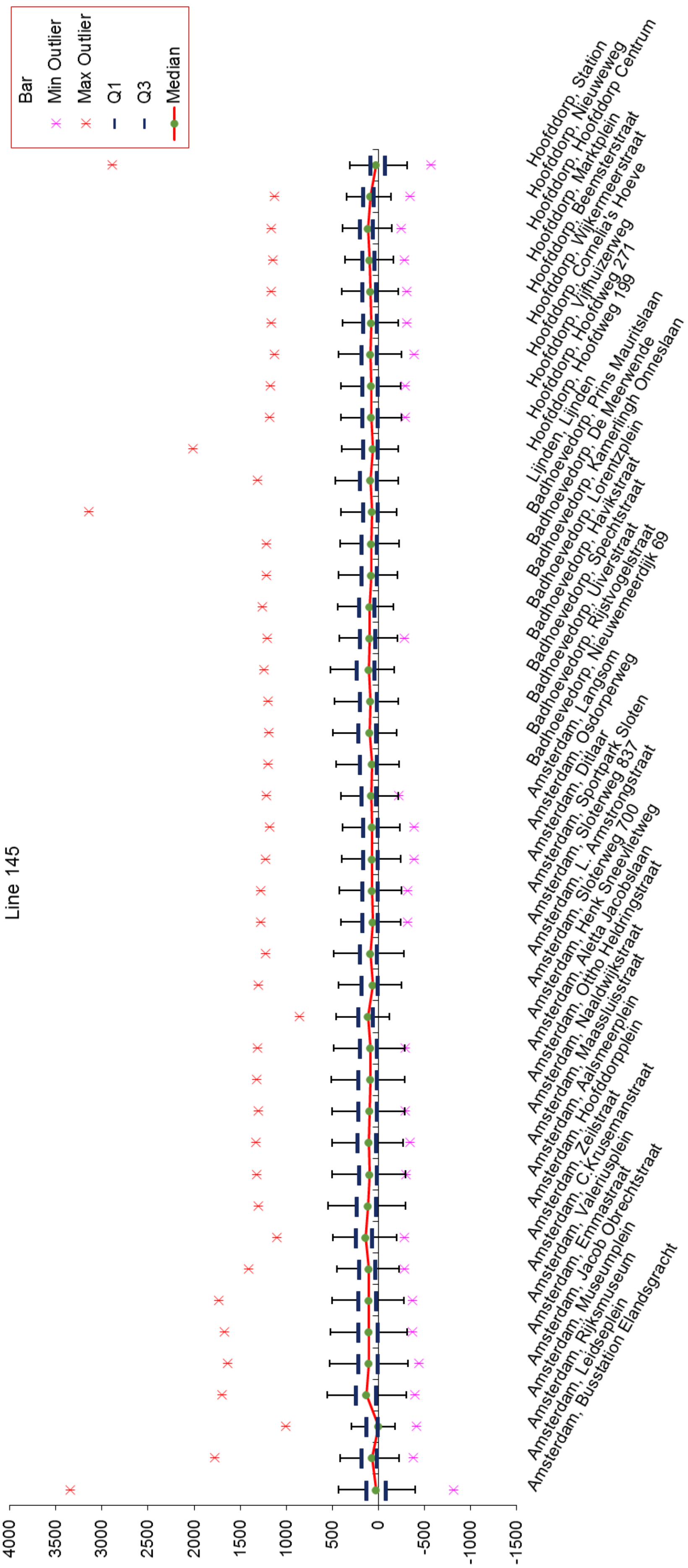
Parameter	Value
$n_{l,j}$ (#)	43
$n_{l,i}$ (#)	2312
p_l (s)	106

Table 55: Average deviation of too late/early departures

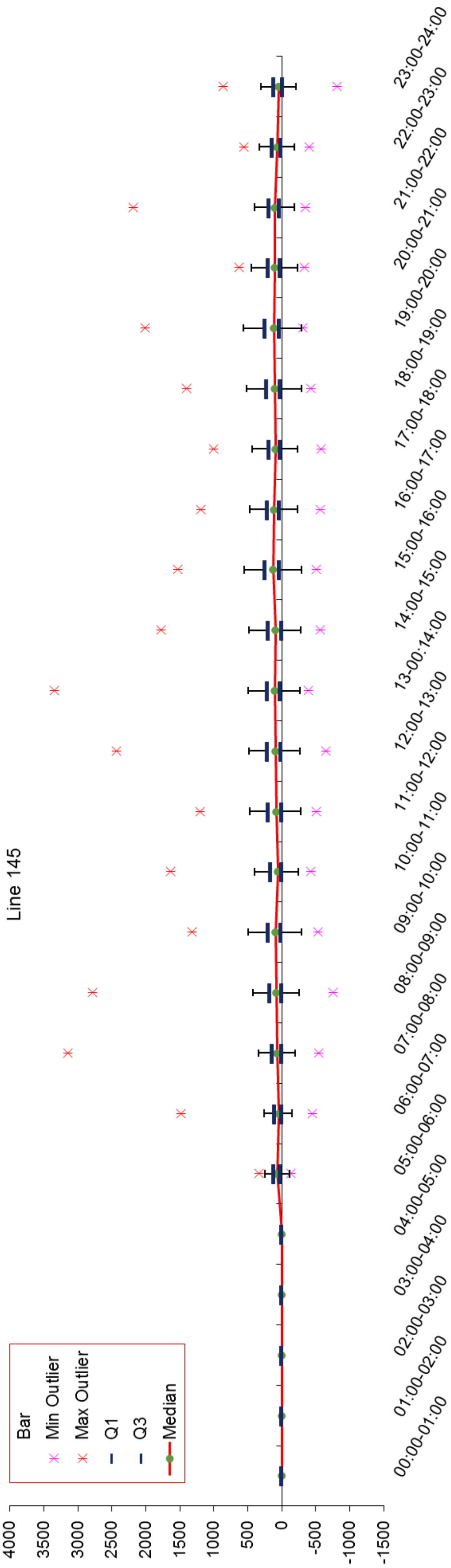
Parameter	Value
$n_{l,j}$ (#)	43
$n_{l,i}$ (#)	2312
p_l (s)	45

Table 56: Percentage of on-time departures of Line 145

# late/early	42877
Total	97893
% on time	56%



Line 145
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
Hoofddorp, Station
Hoofddorp, Nieuweweg
Hoofddorp, Hoofddorp Centrum
Hoofddorp, Marktplein
Hoofddorp, Beemsterstraat
Hoofddorp, Wijkermeerstraat
Hoofddorp, Cornelia's Hoeve
Hoofddorp, Vijfhuizerweg
Hoofddorp, Hoofdweg 271
Hoofddorp, Hoofdweg 199
Lijnden, Lijnden
Badhoevedorp, Prins Mauritslaan
Badhoevedorp, De Meerwende
Badhoevedorp, Kamerlingh Onneslaan
Badhoevedorp, Lorentzplein
Badhoevedorp, Havikstraat
Badhoevedorp, Spechtstraat
Badhoevedorp, Uiverstraat
Badhoevedorp, Rijstvogelstraat
Badhoevedorp, Nieuwemeerdijk 69
Badhoevedorp, Langsom
Amsterdam, Osdorperweg
Amsterdam, Ditlaar
Amsterdam, Sportpark Sloten
Amsterdam, Sloterweg 837
Amsterdam, L. Armstrongstraat
Amsterdam, Sloterweg 700
Amsterdam, Henk Sneevlietweg
Amsterdam, Aletta Jacobslaan
Amsterdam, Ottho Heldringstraat
Amsterdam, Naaldwijkstraat
Amsterdam, Maassluisstraat
Amsterdam, Aalsmeerplein
Amsterdam, Hoofddorpplein
Amsterdam, Zeilstraat
Amsterdam, C.Krusemanstraat
Amsterdam, Valeriusplein
Amsterdam, Emmastraat
Amsterdam, Jacob Obrechtstraat
Amsterdam, Museumplein
Amsterdam, Rijksmuseum
Amsterdam, Leidseplein
Amsterdam, Busstation Elandsgracht



Line 145
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
00:00-01:00
01:00-02:00
02:00-03:00
03:00-04:00
04:00-05:00
05:00-06:00
06:00-07:00
07:00-08:00
08:00-09:00
09:00-10:00
10:00-11:00
11:00-12:00
12:00-13:00
13:00-14:00
14:00-15:00
15:00-16:00
16:00-17:00
17:00-18:00
18:00-19:00
19:00-20:00
20:00-21:00
21:00-22:00
22:00-23:00
23:00-24:00

G.2 Comfortnet – Line 146

Bus line 146 is a 'Green' bus line in Amstelland-Meerlanden, and thus a Comfortnet line. The route of this bus line goes from Amsterdam to Uithoorn. Figure XX presents this route in the concession area Amstelland-Meerlanden.

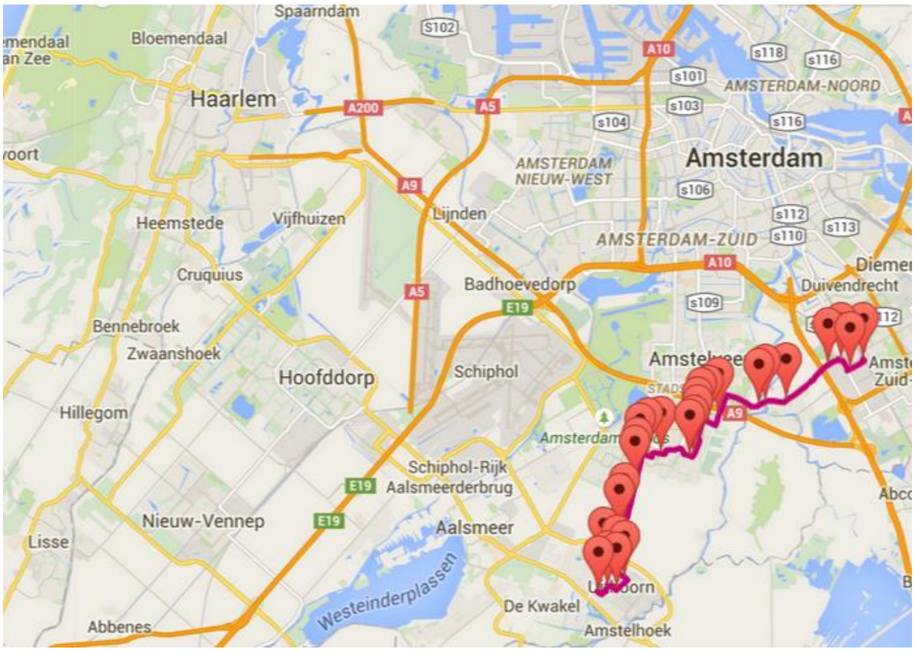


Figure 53: Route of Line 146 (Connexxion, 2015)

General Line Information

End Stop 1	Amsterdam, Bijlmer ArenA
End Stop 2	Uithoorn, Busstation
Frequency peak-hour (times/hour)	4
Frequency off-peak hour (times/hour)	2
Total number of stops (#)	27
Length (km)	16,806
Stop density (stops/km)	1,44
Average stop distance (km)	0,70
Dedicated infrastructure (km)	11,740
Dedicated infrastructure (% of total route)	62%
Number of bus trips (# in March)	1408
Number of passengers (#/week-day)	38

Table 57: General Information of Line 146

Survey Information

Number of passengers (#/week-day)	1350
Number of usable survey responses	38
Confidence interval	95%
Margin of Error	15,68%

Table 58: Survey Information of Line 146

Access and Egress Modalities

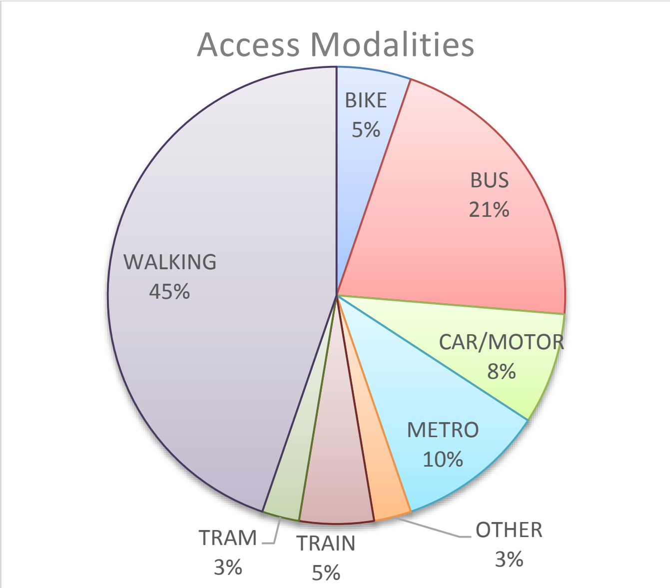


Figure 54: Access Modalities of Line 146

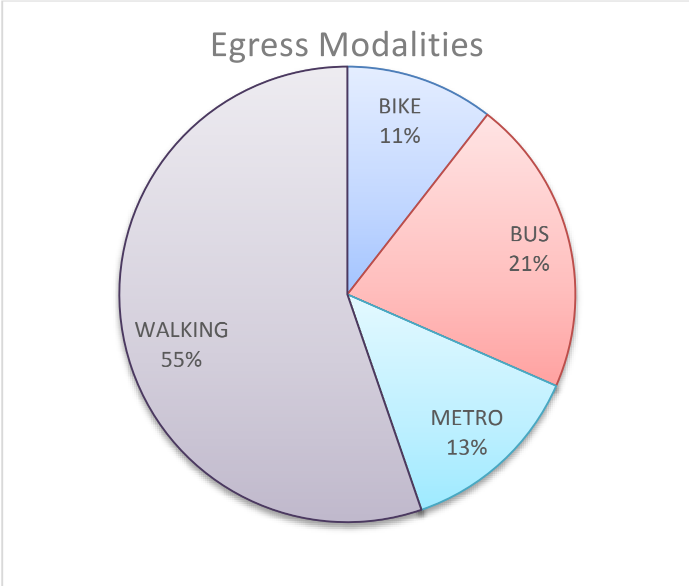


Figure 55: Egress Modalities of Line 146

Modality	Access	%	Egress	
BIKE	2	5%	4	11%
BUS	8	21%	8	21%
CAR/MOTOR	3	8%	0	0%
E-BIKE	0	0%	0	0%
METRO	4	11%	5	13%
OTHER	1	3%	0	0%
MOPED/SCOOTER	0	0%	0	0%
TRAIN	2	5%	0	0%
TRAM	1	3%	0	0%
WALKING	17	45%	21	55%
TOTAL	38	100%	38	100%

Table 59: Access and Egress Modalities for Line 146

Catchment Stop

Table 60: Catchment Area (distance in kilometres) of Bus Stops on Line 146

Access	MIN	P25	MED	P75	MAX
Bike	0,198	-	1,274	-	2,349
Walk	0,395	0,428	0,665	1,042	2,120
Egress	MIN	P25	MED	P75	MAX
Bike	0,4392	0,4557	0,5107	2,2507	2,8289
Walk	0,2237	0,5055	0,5789	0,6653	1,8094

Table 61: Catchment Area (travel time in minutes) of Bus Stops on Line 146

Access	Min	P25	MED	P75	MAX
Bike	0:00:36	-	0:03:49	-	0:07:03
Walk	0:04:44	0:05:08	0:07:59	0:12:30	0:25:27
Egress	Min	P25	MED	P75	MAX
Bike	0:01:19	0:01:22	0:01:32	0:06:45	0:08:29
Walk	0:02:41	0:06:04	0:06:57	0:07:59	0:21:43

Stop Performance

Stop Density

$$Stop\ Density = \frac{\#number\ of\ stops}{line\ lenght} = \frac{27}{16{,}806} = 1{,}61\ {}^{stops}/_{km}$$

Waiting time

Table 62: Waiting Times of Line 146

	Peak Hour	Off-Peak
Frequency (busses/hour)	4	2
Max Waiting time (minutes)	15	30

Classification of Stops

Stop		Number	# stops	% stop (usage)	postal code	Spatial	Activities	#access	#egress	% access	% egress	Stop type
Amsterdam, Bijlmer ArenA	Amsterdam - Bijlmer Arena	1	1145	81%	1101	3	Work/Education	17	9	65%	35%	Access
Amsterdam, Holterbergweg	Amsterdam - Holterbergweg	2	702	50%	1101	3	Work/Education	0	0	0%	0%	Unclear
Amsterdam, de Entree	Amsterdam - de Entree	3	400	28%	1082	1	Residential	0	0	0%	0%	Unclear
Amsterdam, Ventweg	Amsterdam - Ventweg	4	501	36%	1081	1	Work/Education	0	0	0%	0%	Unclear
Ouderkerk a/d Amstel, J. van Ruisdaelweg	Ouderkerk a/d Amstel - J. van Ruisdaelweg	5	690	49%	1191	5	Residential	0	0	0%	0%	Unclear
Ouderkerk a/d Amstel, Brug/Hoger Einde	Ouderkerk a/d Amstel - Brug/Hoger Einde	6	709	50%	1184	5	Work/Education	0	0	0%	0%	Unclear
Ouderkerk a/d Amstel, Brug/Amsteldijk	Ouderkerk a/d Amstel - Brug/Amsteldijk	7	513	36%	1184	5	Work/Education	0	1	0%	100%	Egress
Amstelveen, Langerhuize	Amstelveen - Langerhuize	8	610	43%	1184	5	Work/Education	0	0	0%	0%	Unclear
Amstelveen, Ziekenhuis Hoofdingang	Amstelveen - Ziekenhuis Hoofdingang	9	1101	78%	1186	2	Residential	5	2	71%	29%	Access
Amstelveen, In de Wolken	Amstelveen - In de Wolken	10	751	53%	1181	1	Residential	0	0	0%	0%	Unclear
Amstelveen, Groenhof	Amstelveen - Groenhof	11	1012	72%	1186	2	Residential	0	2	0%	100%	Egress
Amstelveen, Watercirkel	Amstelveen - Watercirkel	13	417	30%	1187	3	Residential	0	0	0%	0%	Unclear
Amstelveen, Seine	Amstelveen - Seine	12	468	33%	1187	3	Residential	0	0	0%	0%	Unclear
Amstelveen, Punter	Amstelveen - Punter	14	841	60%	1186	2	Residential	0	4	0%	100%	Egress
Amstelveen, Grote Beer	Amstelveen - Grote Beer	15	685	49%	1188	2	Work/Education	1	0	100%	0%	Access
Amstelveen, Poortwachter	Amstelveen - Poortwachter	16	1334	95%	1188	2	Work/Education	0	4	0%	100%	Egress
Amstelveen, Zagerij	Amstelveen - Zagerij	18	330	23%	1187	3	Residential	0	0	0%	0%	Unclear
Amstelveen, Nesserlaan	Amstelveen - Nesserlaan	17	178	13%	1185	2	Residential	0	0	0%	0%	Unclear
Amstelveen, Burg. Wiegelweg	Amstelveen - Burg. Wiegelweg	19	471	33%	1185	2	Residential	0	0	0%	0%	Unclear
Amstelveen, Zijdelweg	Amstelveen - Zijdelweg	20	13	1%	1186	2	Residential	0	0	0%	0%	Unclear
Amstelveen, Christinahoeve	Amstelveen - Christinahoeve	21	9	1%	1187	3	Residential	0	0	0%	0%	Unclear
Uithoorn, Willem Klooslaan	Uithoorn - Willem Klooslaan	22	438	31%	1422	3	Residential	1	1	50%	50%	Unclear
Uithoorn, Arth.v.Schendellaan	Uithoorn - Arth v. Schendellaan	23	466	33%	1422	3	Residential	0	0	0%	0%	Unclear
Uithoorn, Heijermanslaan	Uithoorn - Heijermanslaan	24	582	41%	1422	3	Residential	2	0	100%	0%	Access
Uithoorn, Romeflat	Uithoorn - Romeflat	25	900	64%	1422	3	Residential	1	2	33%	67%	Egress
Uithoorn, Achterberglaan	Uithoorn - Achterberglaan	26	639	45%	1422	3	Residential	1	1	50%	50%	Unclear
Uithoorn, Alfons Arienslaan	Uithoorn - Alfons Ariensweg	27	348	25%	1422	3	Residential	1	2	33%	67%	Egress
Uithoorn, Busstation	Uithoorn - Busstation	28	1140	81%	1422	3	Residential	3	7	30%	70%	Egress
TOTAAL			17393	44%						19%	27%	

Table 63: Classification of Stops of Line 146

Table 64: Stop Usage of Line 146

Average stop usage in March (%)		45%
Most used stop	Amstelveen, Poortwachter	95%
Least used stop	Amstelveen, Zijdelweg	1%

Line Performance

Commercial Timetable Speed and In-vehicle time

Table 65: Commercial speed of Line 146

Length of line	16,806
Timetable A to B (h)	32
Commercial time table speed	35
In-vehicle time (min)	17

Trip Cancelations

Table 66: Trip Cancelations of Line 146

# trips	1408
# cancelled	1
% cancelled	0,1%

Punctuality

Table 67: Average deviation from punctuality for all trips on line 146

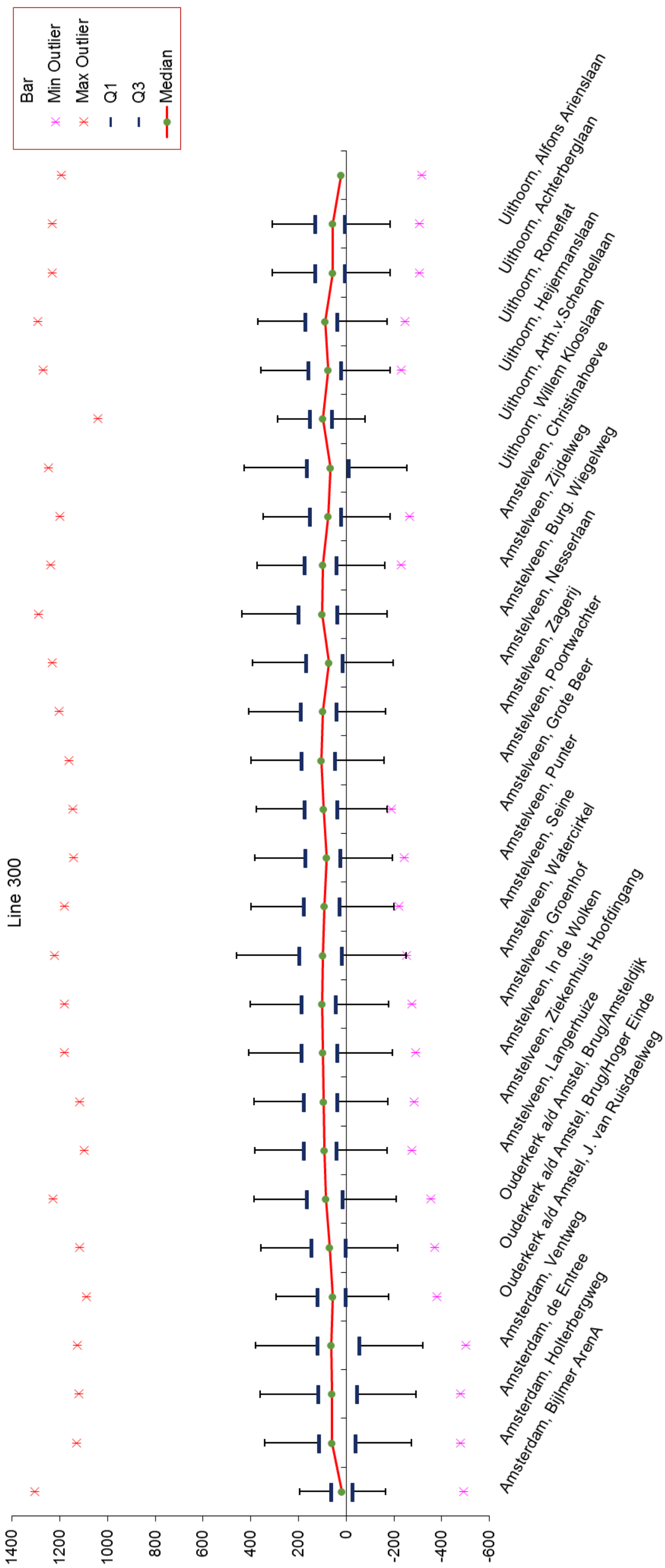
Parameter	Value
$n_{l,j}$ (#)	27
$n_{l,i}$ (#)	1408
p_l (s)	91

Table 68: Average deviation of too late/early departures

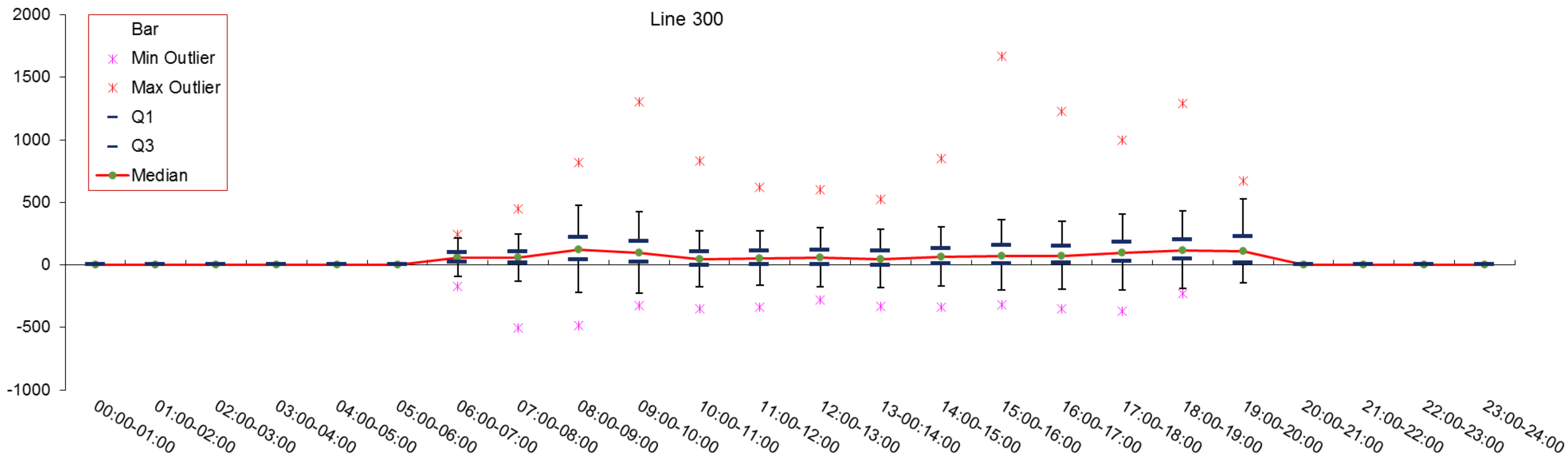
Parameter	Value
$n_{l,j}$ (#)	27
$n_{l,i}$ (#)	1408
p_l (s)	34

Table 69: Percentage of on-time departures of Line 146

# late/early	14322
Total	38016
% on time	62%



Line 300
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
1400
1200
1000
800
600
400
200
0
-200
-400
-600
Uithoorn, Alfons Arienslaan
Uithoorn, Achterberglaan
Uithoorn, Romeflat
Uithoorn, Heijermanslaan
Uithoorn, Arth.v.Schendellaan
Uithoorn, Willem Klooslaan
Amstelveen, Christinahoeve
Amstelveen, Zijdelweg
Amstelveen, Burg. Wiegelweg
Amstelveen, Nesserlaan
Amstelveen, Zagerij
Amstelveen, Poortwachter
Amstelveen, Grote Beer
Amstelveen, Punter
Amstelveen, Seine
Amstelveen, Watercirkel
Amstelveen, Groenhof
Amstelveen, In de Wolken
Amstelveen, Ziekenhuis Hoofdingang
Amstelveen, Langerhuize
Ouderkerk a/d Amstel, Brug/Amsteldijk
Ouderkerk a/d Amstel, Brug/Hoger Einde
Ouderkerk a/d Amstel, J. van Ruisdaelweg
Amsterdam, Ventweg
Amsterdam, de Entree
Amsterdam, Holterbergweg
Amsterdam, Bijlmer ArenA


Line 300
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
2000
1500
1000
500
0
-500
-1000
00:00-01:00
01:00-02:00
02:00-03:00
03:00-04:00
04:00-05:00
05:00-06:00
06:00-07:00
07:00-08:00
08:00-09:00
09:00-10:00
10:00-11:00
11:00-12:00
12:00-13:00
13-00:14:00
14:00-15:00
15:00-16:00
16:00-17:00
17:00-18:00
18:00-19:00
19:00-20:00
20:00-21:00
21:00-22:00
22:00-23:00
23:00-24:00

G.3 Comfortnet – Line 162

Bus line 162 is a 'Green' bus line in Amstelland-Meerlanden, and thus a Comfortnet line. The route of this bus line goes from Lisse to Hoofddorp. Figure XX presents this route in the concession area Amstelland-Meerlanden.

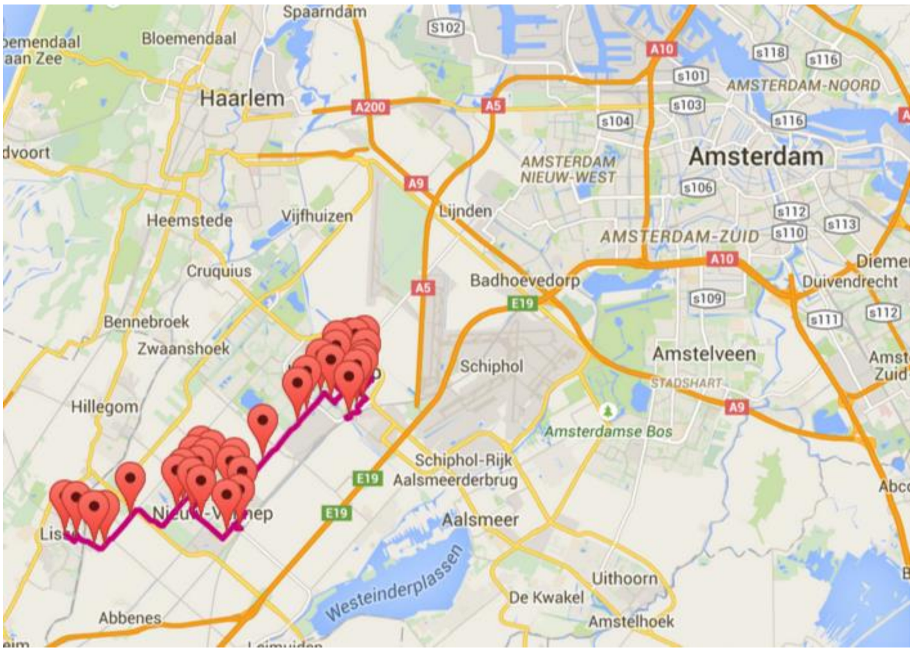


Figure 56: Route of Line 162 (Connexxion, 2015)

General Line Information

End Stop 1	Lisse, Hyacinthenstraat
End Stop 2	Hoofddorp, Station
Frequency peak-hour (times/hour)	1
Frequency off-peak hour (times/hour)	1
Total number of stops (#)	34
Length (km)	21,885
Stop density (stops/km)	1,55
Average stop distance (km)	0,64
Dedicated infrastructure (km)	2,255
Dedicated infrastructure (% of total route)	10%
Number of bus trips (# in March)	1060
Number of passengers (#/week-day)	400

Table 70: General Information of Line 162

Survey Information

Number of passengers (#/week-day)	400
Number of usable survey responses	31
Confidence interval	95%
Margin of Error	16,93%

Table 71: Survey Information of Line 162

Access and Egress Modalities

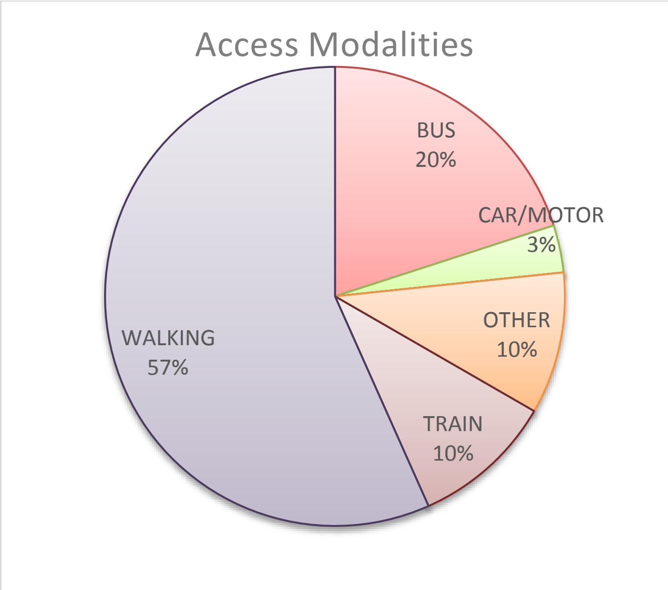


Figure 57: Access Modalities of Line 162

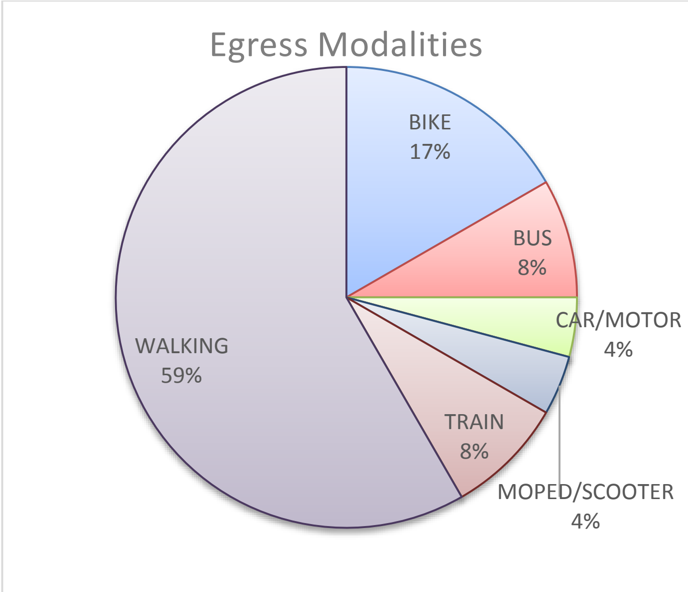


Figure 58: Egress Modalities of Line 162

Modality	Access	%	Egress	
BIKE	0	0%	4	17%
BUS	6	20%	2	8%
CAR/MOTOR	1	3%	1	4%
E-BIKE	0	0%	0	0%
METRO	0	0%	0	0%
OTHER	3	10%	0	0%
MOPED/SCOOTER	0	0%	1	4%
TRAIN	3	10%	2	8%
TRAM	0	0%	0	0%
WALKING	17	57%	14	58%
TOTAL	30	100%	24	100%

Table 72: Access and Egress Modalities for Line 162

Catchment Stop

Table 73: Catchment Area (distance in kilometres) of Bus Stops on Line 162

Access	Min	P25	MED	P75	MAX
Bike	0,000	0,000	0,000	0,000	0,000
Walk	0,132	0,364	0,586	0,710	1,678
Egress	Min	P25	MED	P75	MAX
Bike	0,2971	0,5342	1,2454	1,2454	1,2454
Walk	0,1442	0,2781	0,5228	0,8804	1,2289

Table 74: Catchment Area (travel time in minutes) of Bus Stops on Line 162

Access	Min	P25	MED	P75	MAX
Bike	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
Walk	0:01:35	0:04:22	0:07:02	0:08:31	0:20:08
Egress	Min	P25	MED	P75	MAX
Bike	0:00:53	0:01:36	0:03:44	0:03:44	0:03:44
Walk	0:01:44	0:03:20	0:06:16	0:10:34	0:14:45

Stop Performance

Stop Density

$$Stop\ Density = \frac{\#number\ of\ stops}{line\ lenght} = \frac{34}{21{,}885} = 1{,}55\ {}^{stops}/_{km}$$

Waiting time

Table 75: Waiting Times of Line 162

	Peak Hour	Off-Peak
Frequency (busses/hour)	1	1
Max Waiting time (minutes)	60	60

Classification of Stops

Stop		Number	# stops	% stop (usage)	postal code	Spatial	Activities	#access	#egress	% access	% egress	Stop type
Lisse, Hyacinthenstraat	Lisse - Hyacinthenstraat	1	823	78%	2161	3	Residential	2	5	29%	71%	Egress
Lisse, Narcissenstraat	Lisse - Narcissenstraat	2	205	19%	2165	4	Residential	1	0	100%	0%	Access
Lisserbroek, Kruisbaak	Lisserbroek - Kruisbaak	3	295	28%	2165	4	Residential	1	1	50%	50%	Unclear
Lisserbroek, Bruidsbloemstraat	Lisserbroek - Bruidsbloemstraat	4	294	28%	2165	4	Residential	0	0	0%	0%	Unclear
Nieuw-Vennep, IJweg 1635	Nieuw-Vennep - IJweg 1635	5	28	3%	2153	4	Work/Education	0	0	0%	0%	Unclear
Nieuw-Vennep, Laan van Berlioz	Nieuw-Vennep - Laan van Berlioz	6	192	18%	2151	2	Residential	1	0	100%	0%	Access
Nieuw-Vennep, Getsewoud Zuid	Nieuw-Vennep - Getsewoud Zuid	7	456	43%	2151	2	Residential	2	1	67%	33%	Access
Nieuw-Vennep, Getsewoud Centrum	Nieuw-Vennep - Getsewoud Centrum	8	1027	97%	2152	3	Residential	3	1	75%	25%	Access
Nieuw-Vennep, Laan van Norma	Nieuw-Vennep - Laan van Norma	9	188	18%	2152	3	Residential	0	1	0%	100%	Egress
Nieuw-Vennep, Athenelaan	Nieuw-Vennep - Athenelaan	10	114	11%	2165	4	Residential	0	0	0%	0%	Unclear
Nieuw-Vennep, Westerdreef	Nieuw-Vennep - Westerdreef	11	1	0%	2153	4	Work/Education	0	0	0%	0%	Unclear
Nieuw-Vennep, Raiffeisenstraat	Nieuw-Vennep - Raiffeisenstraat	12	1	0%	2165	4	Residential	0	0	0%	0%	Unclear
Nieuw-Vennep, Westerkim	Nieuw-Vennep - Westerkim	13	6	1%	2151	2	Residential	0	1	0%	100%	Egress
Nieuw-Vennep, Zuiderdreef	Nieuw-Vennep - Zuiderdreef	14	163	15%	2151	2	Residential	0	1	0%	100%	Egress
Nieuw-Vennep, Oosterdreef	Nieuw-Vennep - Oosterdreef	15	112	11%	2153	4	Work/Education	3	0	100%	0%	Access
Nieuw-Vennep, Station	Nieuw-Vennep - Station	16	686	65%	2153	4	Work/Education	1	4	20%	80%	Egress
Nieuw-Vennep, Gersteweg	Nieuw-Vennep - Gersteweg	17	206	19%	2165	4	Residential	0	0	0%	0%	Unclear
Nieuw-Vennep, Haverstraat	Nieuw-Vennep - Haverstraat	18	342	32%	2153	4	Work/Education	2	1	67%	33%	Access
Nieuw-Vennep, Hoofdweg 1194	Nieuw-Vennep - Hoofdweg 1194	19	111	10%	2153	4	Work/Education	0	0	0%	0%	Unclear
Nieuw Vennep, Crematorium	Nieuw Vennep - Crematorium	20	0	0%	2165	4	Residential	0	0	0%	0%	Unclear
Hoofddorp, De President	Hoofddorp - De President	21	97	9%	2135	3	Residential	1	0	100%	0%	Access
Hoofddorp, Jadelaan	Hoofddorp - Jadelaan	22	336	32%	2135	3	Residential	1	0	100%	0%	Access
Hoofddorp, Hoofdweg/Molen	Hoofddorp - Hoofdweg/Molen	23	200	19%	2132	3	Work/Education	0	0	0%	0%	Unclear
Hoofddorp, Nieuweweg	Hoofddorp - Nieuweweg	24	134	13%	2132	3	Work/Education	0	0	0%	0%	Unclear
Hoofddorp, Hoofddorp Centrum	Hoofddorp - Hoofddorp Centrum	25	881	83%	2132	3	Work/Education	2	1	67%	33%	Access
Hoofddorp, Marktplein	Hoofddorp - Marktplein	26	327	31%	2131	3	Residential	1	1	50%	50%	Unclear
Hoofddorp, Draverslaan	Hoofddorp - Draverslaan	26	148	14%	2135	3	Residential	0	0	0%	0%	Unclear
Hoofddorp, Van den Berghlaan	Hoofddorp - Van den Berghlaan	27	251	24%	2132	3	Work/Education	1	1	50%	50%	Unclear
Hoofddorp, Arnolduspark	Hoofddorp - Arnolduspark	28	274	26%	2132	3	Work/Education	0	1	0%	100%	Egress
Hoofddorp, Koning Willem I laan	Hoofddorp - Koning Willem I laan	29	335	32%	2132	3	Work/Education	0	0	0%	0%	Unclear
Hoofddorp, Kalorama	Hoofddorp - Kalorama	30	150	14%	2131	3	Residential	0	0	0%	0%	Unclear
Hoofddorp, Jupiterstraat	Hoofddorp - Jupiterstraat	31	83	8%	2135	3	Residential	0	0	0%	0%	Unclear
Hoofddorp, Saturnusstraat	Hoofddorp - Saturnusstraat	32	94	9%	2131	3	Residential	0	0	0%	0%	Unclear
Hoofddorp, Station	Hoofddorp - Station	33	795	75%	2132	3	Work/Education	6	3	67%	33%	Access
TOTAAL			9355	26%						31%	25%	

Table 76: Classification of Stops of Line 162

Table 77: Stop Usage of Line 162

Average stop usage in March (%)		26%
Most used stop	Nieuw-Vennep, Getsewoud Centrum	97%
Least used stop	Nieuw-Vennep, Westerdreef Nieuw-Vennep, Raifeisenstraat	0%

Line Performance

Commercial Timetable Speed and In-vehicle time

Table 78: Commercial speed of Line 162

Length of line	21,885
Timetable A to B (h)	50
Commercial time table speed	26
In-vehicle time (min)	23

Trip Cancelations

Table 79: Trip Cancelations of Line 162

# trips	1060
# cancelled	1
% cancelled	0,1%

Punctuality

Table 80: Average deviation from punctuality for all trips on line 162

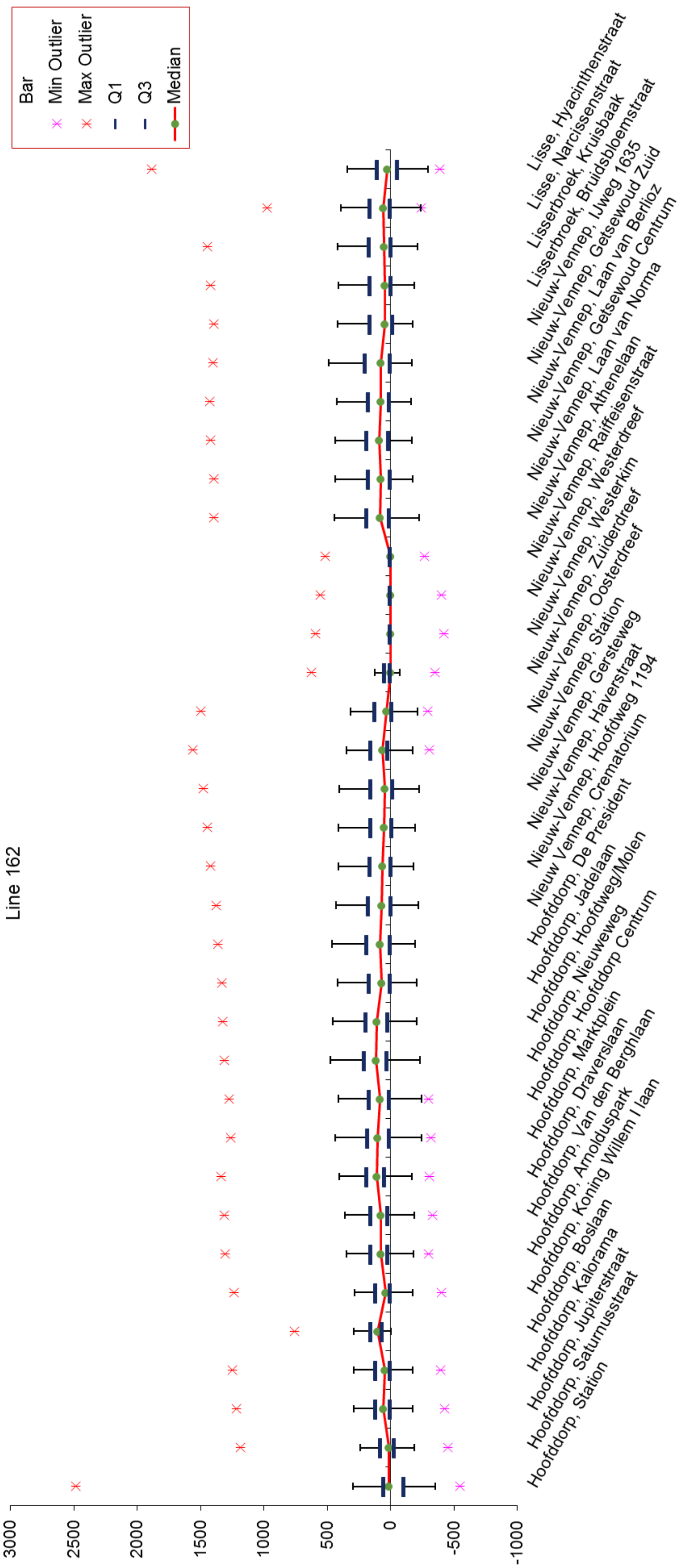
Parameter	Value
$n_{l,j}$ (#)	34
$n_{l,i}$ (#)	1060
p_l (s)	106

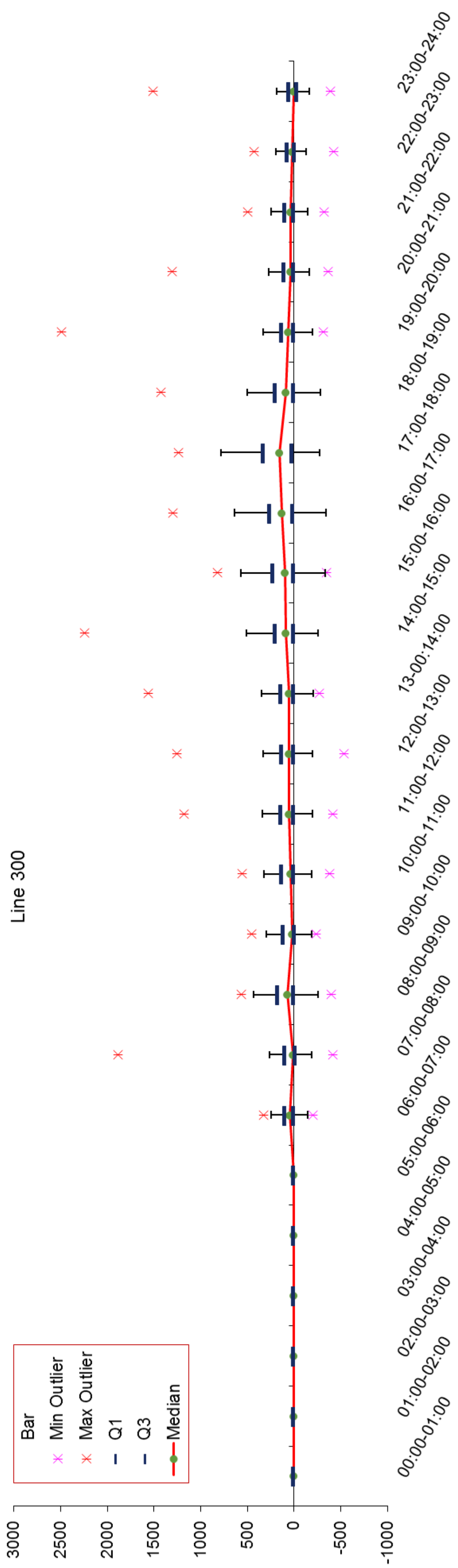
Table 81: Average deviation of too late/early departures on line 162

Parameter	Value
$n_{l,j}$ (#)	34
$n_{l,i}$ (#)	1060
p_l (s)	53

Table 82: Percentage of on-time departures of Line 162

# late/early	13452
Total	33981
% on time	60%


Line 162
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
3000
2500
2000
1500
1000
500
0
-500
-1000
Hoofddorp, Station
Hoofddorp, Saturnusstraat
Hoofddorp, Jupiterstraat
Hoofddorp, Kalorama
Hoofddorp, Boslaan
Hoofddorp, Koning Willem I laan
Hoofddorp, Arnolduspark
Hoofddorp, Van den Berghlaan
Hoofddorp, Draverslaan
Hoofddorp, Marktplein
Hoofddorp, Hoofddorp Centrum
Hoofddorp, Nieuweweg
Hoofddorp, Hoofdweg/Molen
Hoofddorp, Jadelaan
Nieuw Vennep, De President
Nieuw-Vennep, Crematorium
Nieuw-Vennep, Hoofdweg 1194
Nieuw-Vennep, Haverstraat
Nieuw-Vennep, Gersteweg
Nieuw-Vennep, Station
Nieuw-Vennep, Oosterdreef
Nieuw-Vennep, Zuiderdreef
Nieuw-Vennep, Westerkim
Nieuw-Vennep, Westerdreef
Nieuw-Vennep, Raiffeisenstraat
Nieuw-Vennep, Athenelaan
Nieuw-Vennep, Laan van Norma
Nieuw-Vennep, Getsewoud Centrum
Nieuw-Vennep, Laan van Berlioz
Nieuw-Vennep, Getsewoud Zuid
Nieuw-Vennep, IJweg 1635
Lisserbroek, Bruidsbloemstraat
Lisserbroek, Kruisbaak
Lisse, Narcissenstraat
Lisse, Hyacinthenstraat


Line 300
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
3000
2500
2000
1500
1000
500
0
-500
-1000
00:00-01:00
01:00-02:00
02:00-03:00
03:00-04:00
04:00-05:00
05:00-06:00
06:00-07:00
07:00-08:00
08:00-09:00
09:00-10:00
10:00-11:00
11:00-12:00
12:00-13:00
13:00-14:00
14:00-15:00
15:00-16:00
16:00-17:00
17:00-18:00
18:00-19:00
19:00-20:00
20:00-21:00
21:00-22:00
22:00-23:00
23:00-24:00

G.4 Comfortnet – Line 172

Bus line 172 is a 'Green' bus line in Amstelland-Meerlanden, and thus a Comfortnet line. The route of this bus line goes from Lisse to Hoofddorp. Figure XX presents this route in the concession area Amstelland-Meerlanden.

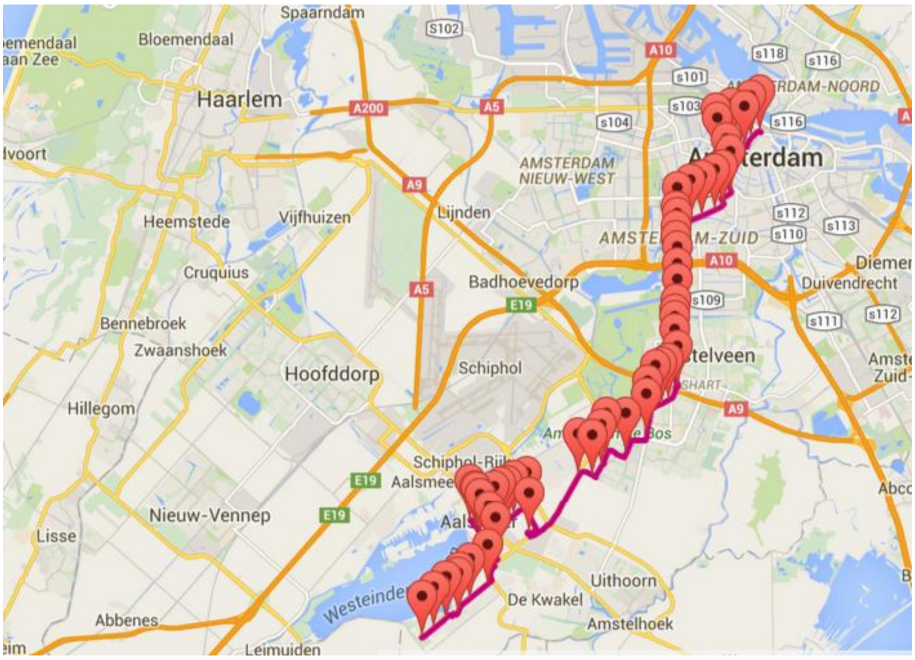


Figure 59: Route of Line 172 (Connexxion, 2015)

General Line Information

End Stop 1	Kudelstaart, Bilderdammerweg
End Stop 2	Amsterdam, Centraal Station
Frequency peak-hour (times/hour)	6
Frequency off-peak hour (times/hour)	3
Total number of stops (#)	55
Length (km)	29,414
Stop density (stops/km)	1,87
Average stop distance (km)	0,54
Dedicated infrastructure (km)	7,395
Dedicated infrastructure (% of total route)	25%
Number of bus trips (# in March)	4502
Number of passengers (#/week-day)	8050

Table 83: General Information of Line 172

Survey Information

Number of passengers (#/week-day)	8050
Number of usable survey responses	136
Confidence interval	95%
Margin of Error	8,33%

Table 84: Survey Information of Line 172

Access and Egress Modalities

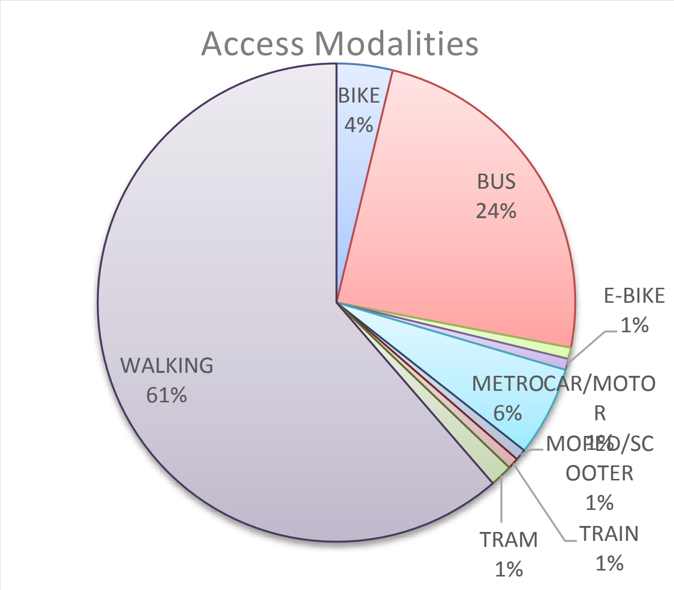


Figure 60: Access Modalities of Line 172

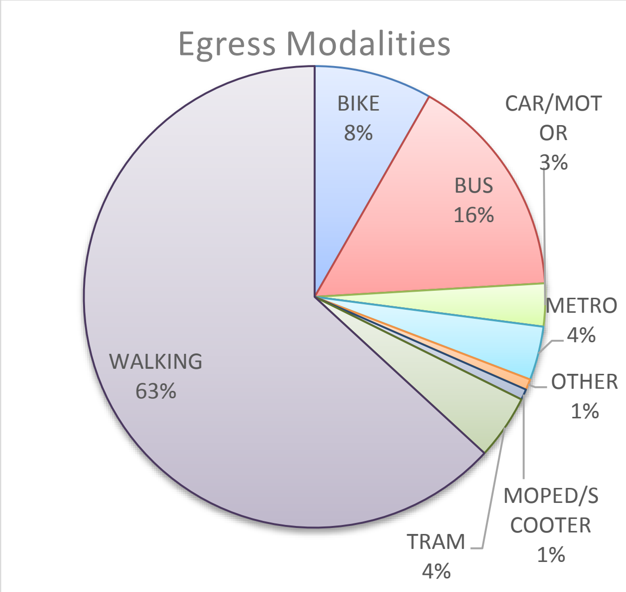


Figure 61: Egress Modalities of Line 172

Modality	Access	%	Egress	
BIKE	5	4%	11	8%
BUS	32	24%	21	16%
CAR/MOTOR	1	1%	4	3%
E-BIKE	1	1%	0	0%
METRO	8	6%	5	4%
OTHER	0	0%	1	1%
MOPED/SCOOTER	1	1%	1	1%
TRAIN	1	1%	0	0%
TRAM	2	2%	6	5%
WALKING	81	61%	84	63%
TOTAL	132	100%	133	100%

Table 85: Access and Egress Modalities for Line 172

Catchment Stop

Table 86: Catchment Area (distance in kilometres) of Bus Stops on Line 172

Access	Min	P25	MED	P75	MAX
Bike	0,063	0,548	1,033	3,217	3,440
Walk	0,029	0,300	0,683	1,033	3,477
Egress	Min	P25	MED	P75	MAX
Bike	0,0726	0,0866	0,6334	1,3903	4,9815
Walk	0,0292	0,3327	0,6069	0,9984	25,5026

Table 87: Catchment Area (travel time in minutes) of Bus Stops on Line 172

Access	Min	P25	MED	P75	MAX
Bike	0:00:11	0:01:39	0:03:06	0:09:39	0:10:19
Walk	0:00:21	0:03:36	0:08:11	0:12:24	0:41:44

Egress	Min	P25	MED	P75	MAX
Bike	0:00:13	0:00:16	0:01:54	0:04:10	0:14:57
Walk	0:00:21	0:04:00	0:07:17	0:11:59	5:06:02

Stop Performance

Stop Density

$$Stop\ Density = \frac{\#number\ of\ stops}{line\ lenght} = \frac{55}{29{,}414} = 1{,}87\ {}^{stops}/_{km}$$

Waiting time

Table 88: Waiting Times of Line 172

	Peak Hour	Off-Peak
Frequency (busses/hour)	6	3
Max Waiting time (minutes)	10	20

Classification of Stops

Stop		Number	# stops	% stop (usage)	postal code	Spatial	Activities	#access	#egress	% access	% egress	Stop type
Kudelstaart, Bilderdammerweg	Kudelstaart - Bilderdammerweg	1	2402	53%	2131	3	Residential	0	0	0%	0%	Unclear
Kudelstaart, Calslager Bancken	Kudelstaart - Calslager Bancken	2	1199	27%	2131	3	Residential	0	0	0%	0%	Unclear
Kudelstaart, Gravin Aleidstraat	Kudelstaart - Gravin Aleidstraat	3	1014	23%	2131	3	Residential	0	0	0%	0%	Unclear
Kudelstaart, Schweitzerstraat	Kudelstaart - Schweitzerstraat	4	1728	38%	2131	3	Residential	0	0	0%	0%	Unclear
Kudelstaart, Einsteinstraat	Kudelstaart - Einsteinstraat	5	1211	27%	2131	3	Residential	0	0	0%	0%	Unclear
Kudelstaart, De Rietlanden	Kudelstaart - De Rietlanden	6	1615	36%	2131	3	Residential	0	0	0%	0%	Unclear
Kudelstaart, Legmeerdijk	Kudelstaart - Legmeerdijk	7	480	11%	2131	3	Residential	0	0	0%	0%	Unclear
Aalsmeer, Mozartlaan	Aalsmeer - Mozartlaan	8	698	16%	1431	4	Mixed	0	0	0%	0%	Unclear
Aalsmeer, Beethovenlaan	Aalsmeer - Beethovenlaan	9	1001	22%	1431	4	Mixed	0	2	0%	100%	Egress
Aalsmeer, Zwarteweg	Aalsmeer - Zwarteweg	10	2997	67%	1431	4	Residential	3	3	50%	50%	Unclear
Aalsmeer, Gloxiniastraat	Aalsmeer - Gloxiniastraat	11	1347	30%	1431	4	Mixed	4	0	100%	0%	Access
Aalsmeer, Hortensiaplein	Aalsmeer - Hortensiaplein	12	4085	91%	1431	4	Mixed	13	8	62%	38%	Access
Aalsmeer, Gloxiniastraat	Aalsmeer - Gloxiniastraat	13	1347	30%	1431	4	Mixed	4	0	100%	0%	Access
Aalsmeer, Zwarteweg	Aalsmeer - Zwarteweg	14	2997	67%	1431	4	Mixed	3	3	50%	50%	Unclear
Aalsmeer, Mendelstraat	Aalsmeer - Mendelstraat	15	1003	22%	1431	4	Mixed	0	0	0%	0%	Unclear
Aalsmeer, P.F.von Sieboldlaan	Aalsmeer - P.F.von Sieboldlaan	16	1922	43%	1431	4	Mixed	0	0	0%	0%	Unclear
Aalsmeer, Floraholland West	Aalsmeer - Floraholland West	17	493	11%	1431	4	Mixed	1	0	100%	0%	Access
Aalsmeer, Floraholland Noord	Aalsmeer - Floraholland Noord	18	1288	29%	1431	4	Mixed	0	0	0%	0%	Unclear
Aalsmeer, Floraholland Oost	Aalsmeer - Floraholland Oost	19	931	21%	1432	5	Residential	1	0	100%	0%	Access
Aalsmeer, Floraholland Hoofdingang	Aalsmeer - Floraholland Hoofdingang	20	2007	45%	1431	4	Mixed	8	1	89%	11%	Access
Aalsmeer, Nieuw Oosteinde	Aalsmeer - Nieuw Oosteinde	21	3025	67%	1432	5	Work/Education	0	0	0%	0%	Unclear
Amstelveen, Weldam	Amstelveen - Weldam	22	1726	38%	1187	3	Residential	0	1	0%	100%	Egress
Amstelveen, Cannenburgh	Amstelveen - Cannenburgh	23	2703	60%	1187	3	Residential	2	3	40%	60%	Egress
Amstelveen, Westwijkplein	Amstelveen - Westwijkplein	24	4305	96%	1187	3	Residential	3	4	43%	57%	Egress
Amstelveen, Sacharovlaan	Amstelveen - Sacharovlaan	25	3677	82%	1187	3	Residential	4	6	40%	60%	Egress
Amstelveen, Bovenkerkerweg	Amstelveen - Bovenkerkerweg	26	2883	64%	1185	2	Residential	2	4	33%	67%	Egress
Amstelveen, Handweg	Amstelveen - Handweg	27	3279	73%	1185	2	Residential	3	2	60%	40%	Access
Amstelveen, Lindenlaan	Amstelveen - Lindenlaan	28	2972	66%	1185	2	Residential	0	0	0%	0%	Unclear
Amstelveen, Icaruslaan	Amstelveen - Icaruslaan	29	1462	32%	1181	1	Residential	0	0	0%	0%	Unclear
Amstelveen, Keizer Karelplein	Amstelveen - Keizer Karelplein	30	1796	40%	1182	4	Leisure/Shopping	0	0	0%	0%	Unclear
Amstelveen, Busstation	Amstelveen - Busstation	31	4377	97%	1185	2	Residential	27	16	63%	37%	Access
Amstelveen, Heemraadschapslaan	Amstelveen - Heemraadschapslaan	32	2136	47%	1181	1	Residential	0	5	0%	100%	Egress
Amstelveen, Kruiskerk	Amstelveen - Kruiskerk	33	2738	61%	1182	4	Leisure/Shopping	0	0	0%	0%	Unclear
Amstelveen, Dijkgravenlaan	Amstelveen - Dijkgravenlaan	34	1603	36%	1181	1	Residential	1	0	100%	0%	Access
Amstelveen, Graaf Florislaan	Amstelveen - Graaf Florislaan	35	2669	59%	1181	1	Residential	4	2	67%	33%	Access
Amsterdam, Kalfjeslaan	Amsterdam - Kalfjeslaan	36	3106	69%	1081	1	Work/Education	1	3	25%	75%	Egress
Amsterdam, Van Nijenrodeweg	Amsterdam - Van Nijenrodeweg	37	2523	56%	1081	1	Residential	2	0	100%	0%	Access
Amsterdam, Koenenkade	Amsterdam - Koenenkade	38	1953	43%	1081	1	Work/Education	0	0	0%	0%	Unclear
Amsterdam, VU Medisch Centrum	Amsterdam - VU Medisch Centrum	39	2875	64%	1081	1	Work/Education	2	2	50%	50%	Unclear
Amsterdam, Amstelveenseweg	Amsterdam - Amstelveenseweg	40	4366	97%	1076	1	Mixed	2	3	40%	60%	Egress
Amsterdam, IJsbaanpad	Amsterdam - IJsbaanpad	41	1937	43%	1076	1	Mixed	1	0	100%	0%	Access
Amsterdam, Olympisch Stadion	Amsterdam - Olympisch Stadion	42	2621	58%	1076	1	Mixed	0	0	0%	0%	Unclear
Amsterdam, Haarlemmermeerstation	Amsterdam - Haarlemmermeerstation	43	3730	83%	1075	1	Mixed	1	1	50%	50%	Unclear
Amsterdam, Valeriusplein	Amsterdam - Valeriusplein	44	2468	55%	1075	1	Mixed	2	1	67%	33%	Access
Amsterdam, Emmastraat	Amsterdam - Emmastraat	45	2282	51%	1071	1	Leisure/Shopping	1	1	50%	50%	Unclear
Amsterdam, Jacob Obrechtstraat	Amsterdam - Jacob Obrechtstraat	46	1720	38%	1071	1	Residential	0	0	0%	0%	Unclear
Amsterdam, Museumplein	Amsterdam - Museumplein	47	3737	83%	1071	1	Leisure/Shopping	5	3	63%	38%	Access
Amsterdam, Rijksmuseum	Amsterdam - Rijksmuseum	48	1532	34%	1071	1	Leisure/Shopping	1	1	50%	50%	Unclear
Amsterdam, Leidseplein	Amsterdam - Leidseplein	49	4271	95%	1017	1	Work/Education	2	4	33%	67%	Egress
Amsterdam, Elandsgracht	Amsterdam - Elandsgracht	50	3141	70%	1016	1	Residential	4	2	67%	33%	Access
Amsterdam, Marnixstraat	Amsterdam - Marnixstraat	51	2970	66%	1016	1	Residential	3	4	43%	57%	Egress
Amsterdam, Westermarkt	Amsterdam - Westermarkt	52	3012	67%	1016	1	Residential	4	4	50%	50%	Unclear
Amsterdam, Dam	Amsterdam - Dam	53	2495	55%	1012	1	Leisure/Shopping	2	1	67%	33%	Access
Amsterdam, Nieuwezijds Kolk	Amsterdam - Nieuwezijds Kolk	54	1590	35%	1012	1	Leisure/Shopping	0	7	0%	100%	Egress
Amsterdam, Centraal Station	Amsterdam - Centraal Station	55	3759	83%	1012	1	Residential	6	8	43%	57%	Egress
TOTAAL			129204	52%						36%	29%	

Table 89: Classification of Stops of Line 172

Table 90: Stop Usage of Line 172

Average stop usage in March (%)		52%
Most used stop	Amsterdam, Amstelveenseweg	97%
Least used stop	Aalsmeer, FloraHolland West Kudelstaart, Legmeerdijk	0%

Line Performance

Commercial Timetable Speed and In-vehicle time

Table 91: Commercial speed of Line 172

Length of line	29,414
Timetable A to B (h)	82
Commercial time table speed	22

In-vehicle time (min)	27

Trip Cancelations

Table 92: Trip Cancelations of Line 172

# trips	4502
# cancelled	12
% cancelled	0,3%

Punctuality

Table 93: Average deviation from punctuality for all trips on line 172

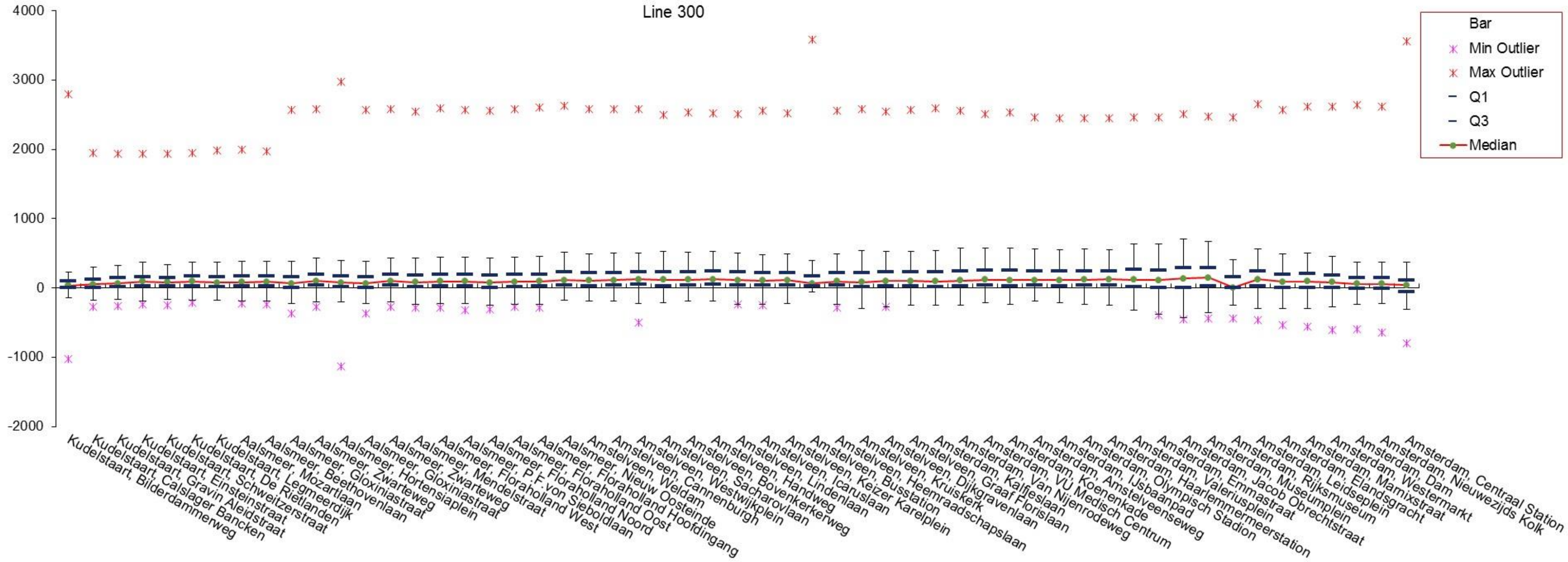
Parameter	Value
$n_{l,j}$ (#)	55
$n_{l,i}$ (#)	4502
p_l (s)	130

Table 94: Average deviation of too late/early departures on line 172

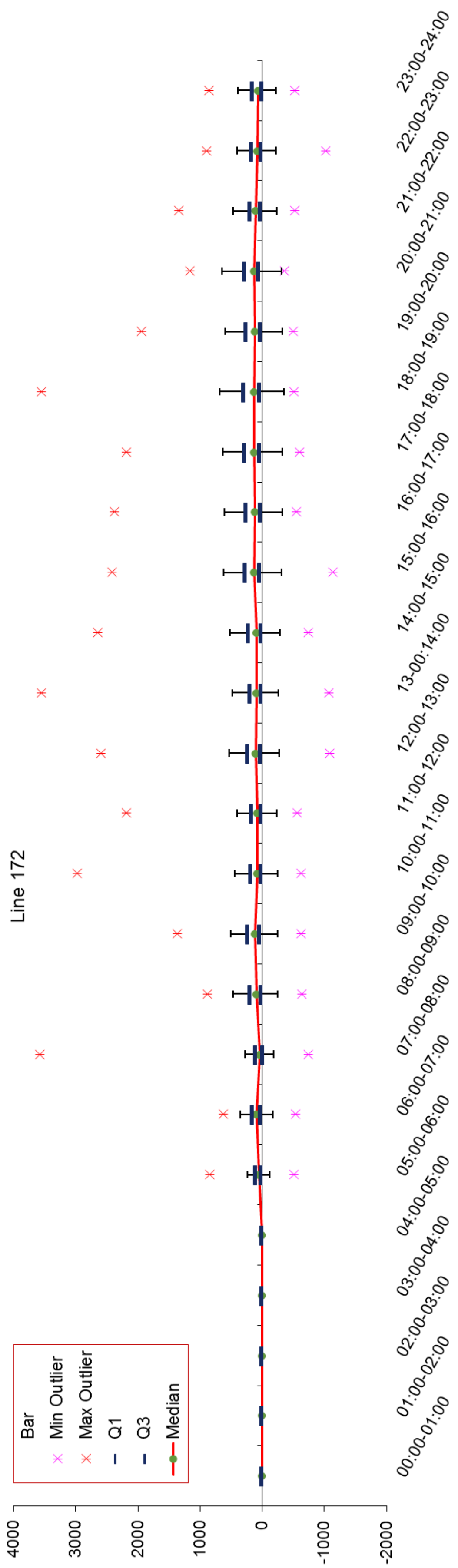
Parameter	Value
$n_{l,j}$ (#)	55
$n_{l,i}$ (#)	4502
p_l (s)	62

Table 95: Percentage of on-time departures of Line 172

# late/early	102858
Total	230583
% on time	55%



Line 300
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
4000
3000
2000
1000
0
-1000
-2000
Kudelstaart, Bilderdammerweg
Kudelstaart, Calslager Bancken
Kudelstaart, Gravin Aleidstraat
Kudelstaart, Einsteinstraat
Kudelstaart, Schweitzerstraat
Kudelstaart, De Rietlanden
Kudelstaart, Legmeerdijk
Aalsmeer, Mozartlaan
Aalsmeer, Beethovenlaan
Aalsmeer, Gloxiniastraat
Aalsmeer, Zwarteweg
Aalsmeer, Hortensiaplein
Aalsmeer, Gloxiniastraat
Aalsmeer, Zwarteweg
Aalsmeer, Mendelstraat
Aalsmeer, Floraholland West
Aalsmeer, P.F. von Sieboldlaan
Aalsmeer, Floraholland Noord
Aalsmeer, Floraholland Oost
Aalsmeer, Floraholland Hoofdingang
Aalsmeer, Nieuw Oosteinde
Amstelveen, Weldam
Amstelveen, Cannenburgh
Amstelveen, Westwijkplein
Amstelveen, Sacharovlaan
Amstelveen, Bovenkerkerweg
Amstelveen, Handweg
Amstelveen, Lindenlaan
Amstelveen, Icaruslaan
Amstelveen, Keizer Karelplein
Amstelveen, Busstation
Amstelveen, Heemraadschapslaan
Amstelveen, Kruiskerk
Amstelveen, Dijkgravenlaan
Amsterdam, Graaf Florislaan
Amsterdam, Kalfjeslaan
Amsterdam, Van Nijenrodeweg
Amsterdam, VU Medisch Centrum
Amsterdam, Koenenkade
Amsterdam, Amstelveenseweg
Amsterdam, IJsbaanpad
Amsterdam, Olympisch Stadion
Amsterdam, Haarlemmermeerstation
Amsterdam, Valeriusplein
Amsterdam, Emmastraat
Amsterdam, Jacob Obrechtstraat
Amsterdam, Museumplein
Amsterdam, Rijksmuseum
Amsterdam, Leidseplein
Amsterdam, Elandsgracht
Amsterdam, Marnixstraat
Amsterdam, Westermarkt
Amsterdam, Dam
Amsterdam, Nieuwezijds Kolk
Amsterdam, Centraal Station



Line 172
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
4000
3000
2000
1000
0
-1000
-2000
00:00-01:00
01:00-02:00
02:00-03:00
03:00-04:00
04:00-05:00
05:00-06:00
06:00-07:00
07:00-08:00
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19:00-20:00
20:00-21:00
21:00-22:00
22:00-23:00
23:00-24:00

G.5 Comfortnet – Line 187

Bus line 187 is a 'Green' bus line in Amstelland-Meerlanden, and thus a Comfortnet line. The route of this bus line goes from Lisse to Hoofddorp. Figure XX presents this route in the concession area Amstelland-Meerlanden.

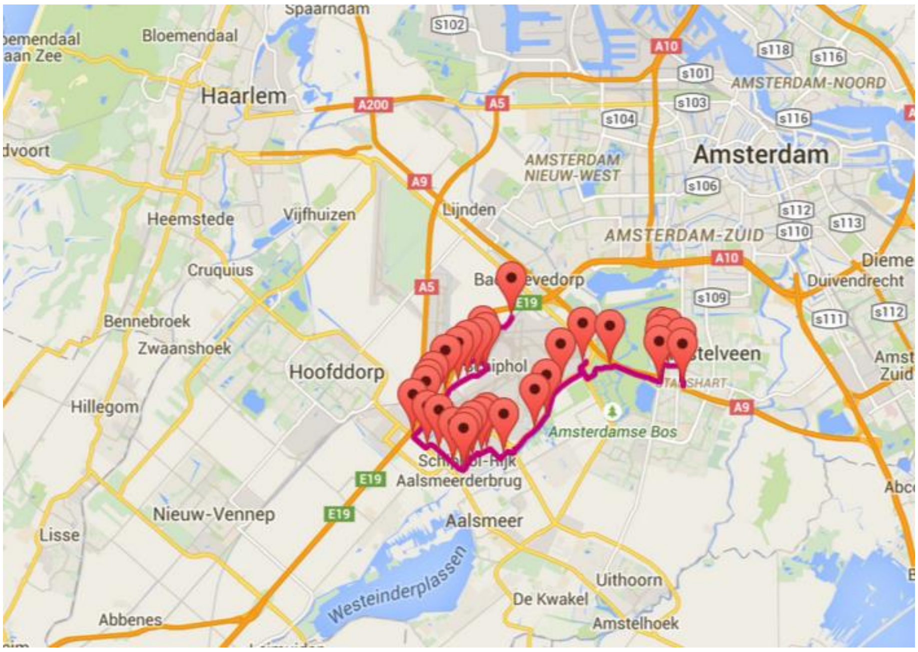


Figure 62: Route of Line 187 (Connexxion, 2015)

General Line Information

End Stop 1	Schiphol Noord, P40 / Schiphol Zuid P30
End Stop 2	Amstelveen, Busstation
Frequency peak-hour (times/hour)	4
Frequency off-peak hour (times/hour)	4
Total number of stops (#)	31
Length (km)	26,553
Stop density (stops/km)	1,17
Average stop distance (km)	0,86
Dedicated infrastructure (km)	3,650
Dedicated infrastructure (% of total route)	14%
Number of bus trips (# in March)	2398
Number of passengers (#/week-day)	1950[1]

Table 96: General Information of Line 187

Survey Information

Number of passengers (#/week-day)	1950
Number of usable survey responses	13
Confidence interval	95%
Margin of Error	17,47%

Table 97: Survey Information of Line 187

Access and Egress Modalities

[1] Line number changes of the route, so number of passengers per week day is an estimation.

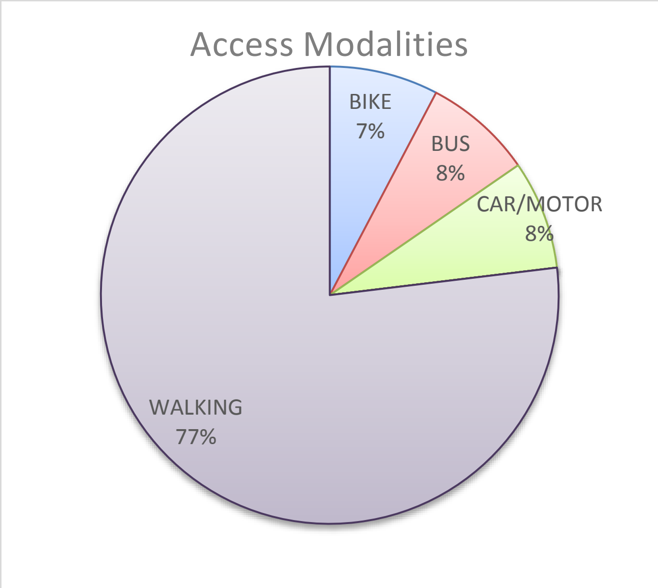


Figure 63: Access Modalities of Line 187

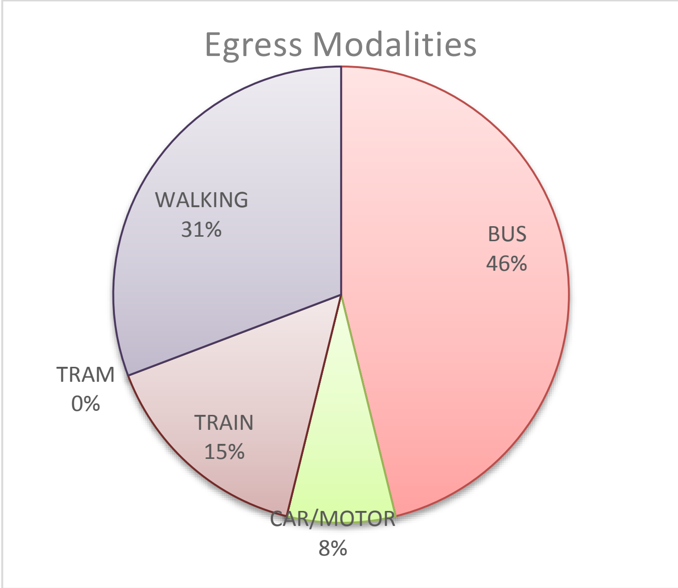


Figure 64: Egress Modalities of Line 187

Modality	Access	%	Egress	
BIKE	1	8%	0	0%
BUS	1	8%	6	46%
CAR/MOTOR	1	8%	1	8%
E-BIKE	0	0%	0	0%
METRO	0	0%	0	0%
OTHER	0	0%	0	0%
MOPED/SCOOTER	0	0%	0	0%
TRAIN	0	0%	2	15%
TRAM	0	0%	0	0%
WALKING	10	77%	4	31%
TOTAL	13	100%	13	100%

Table 98: Access and Egress Modalities for Line 187

Catchment Stop

Table 99: Catchment Area (distance in kilometres) of Bus Stops on Line 187

Access	Min	P25	MED	P75	MAX
Bike	2,580	-	2,580	-	2,580
Walk	0,114	0,266	0,425	1,021	2,138
Egress	Min	P25	MED	P75	MAX
Bike	0,0000	-	-	-	0,0000
Walk	0,3619	-	0,3932	-	0,4245

Table 100: Catchment Area (travel time in minutes) of Bus Stops on Line 187

Access	Min	P25	MED	P75	MAX
Bike	0:07:44	-	0:07:44	-	0:07:44
Walk	0:01:22	0:03:12	0:05:06	0:12:15	0:25:40
Egress	Min	P25	MED	P75	MAX
Bike	0:00:00	-	-	-	0:00:00
Walk	0:04:21	-	0:04:43	-	0:05:06

Stop Performance

Stop Density

$$Stop\ Density = \frac{\#number\ of\ stops}{line\ lenght} = \frac{31}{26{,}553} = 1{,}17\ {}^{stops}/_{km}$$

Waiting time

Table 101: Waiting Times of Line 187

	Peak Hour	Off-Peak
Frequency (busses/hour)	4	4
Max Waiting time (minutes)	15	15

Classification of Stops

Stop		Number	# stops	% stop (usage)	postal code	Spatial	Activities	#access	#egress	% access	% egress	Stop type
Schiphol Noord, P40 Parkeerterrein	Schiphol Noord - P40 Parkeerterrein	1	186	8%	1171	3	Residential	0	0	0%	0%	Unclear
Schiphol Centrum, Airport/Plaza	Schiphol Centrum - Airport/Plaza	2	891	37%	1118	5	Work/Education	1	1	50%	50%	Unclear
Skyport	Skyport	3	805	34%	1437	3	Work/Education	0	0	0%	0%	Unclear
Havenmeesterweg	Havenmeesterweg	4	629	26%	2012	1	0	0	0	0%	0%	Unclear
Vrachtgebouw /P12	Vrachtgebouw /P12	5	595	25%	2141	4	Mixed	0	0	0%	0%	Unclear
Schipholgebouw	Schipholgebouw	6	663	28%	1437	3	Work/Education	0	0	0%	0%	Unclear
Uiverweg	Uiverweg	7	224	9%	1422	3	Residential	0	0	0%	0%	Unclear
Schiphol Zuid, Toekanweg	Schiphol Zuid - Toekanweg	8	450	19%	1437	3	Work/Education	0	0	0%	0%	Unclear
Schiphol Zuid, Valkweg	Schiphol Zuid - Valkweg	9	571	24%	1437	3	Work/Education	0	0	0%	0%	Unclear
Schiphol Zuid, P30 Parkeerterrein	Schiphol Zuid - P30 Parkeerterrein	10	1731	72%	1437	3	Work/Education	1	0	100%	0%	Access
Rozenburg, Kruisweg	Rozenburg - Kruisweg	11	60	3%	1191	5	Residential	0	0	0%	0%	Unclear
Rozenburg, Kruisweg 365	Rozenburg - Kruisweg 365	12	71	3%	1191	5	Residential	0	0	0%	0%	Unclear
Rozenburg, Aalsmeerderweg	Rozenburg - Aalsmeerderweg	13	139	6%	1191	5	Residential	0	0	0%	0%	Unclear
Schiphol-Rijk, Beechavenue	Schiphol-Rijk - Beechavenue	14	1828	76%	1437	3	Work/Education	0	0	0%	0%	Unclear
Schiphol-Rijk, Boeingavenue	Schiphol-Rijk - Boeingavenue	15	1294	54%	1437	3	Work/Education	0	0	0%	0%	Unclear
Schiphol-Rijk, Tupolevlaan/Boeingav	Schiphol-Rijk - Tupolevlaan/Boeingav	16	1444	60%	1437	3	Work/Education	0	0	0%	0%	Unclear
Schiphol-Rijk, Tupolevlaan	Schiphol-Rijk - Tupolevlaan	17	502	21%	1437	3	Work/Education	0	0	0%	0%	Unclear
Schiphol-Rijk, Bellsingel	Schiphol-Rijk - Bellsingel	18	1217	51%	1437	3	Work/Education	0	0	0%	0%	Unclear
Schiphol-Rijk, Douglassingel	Schiphol-Rijk - Douglassingel	19	1493	62%	1437	3	Work/Education	0	0	0%	0%	Unclear
Schiphol Rijk, Capronilaan	Schiphol Rijk - Capronilaan	20	1136	47%	1119	5	Work/Education	0	0	0%	0%	Unclear
Oude Meer, Fokker	Oude Meer - Fokker	21	55	2%	1438	5	Work/Education	0	1	0%	100%	Egress
Oude Meer, Fokker Logistics Park	Oude Meer - Fokker Logistics Park	22	927	39%	1438	5	Work/Education	1	0	100%	0%	Access
Oude Meer, Hangar 9/10	Oude Meer - Hangar 9/10	23	4	0%	1438	5	Work/Education	0	0	0%	0%	Unclear
Schiphol Oost, Stationsplein	Schiphol Oost - Stationsplein	24	1724	72%	1117	3	Work/Education	1	2	33%	67%	Egress
Amstelveen, Nieuwe Meerlaan	Amstelveen - Nieuwe Meerlaan	25	70	3%	1185	2	Residential	0	0	0%	0%	Unclear
Amstelveen, Dorpsstraat	Amstelveen - Dorpsstraat	26	597	25%	1181	1	Residential	0	0	0%	0%	Unclear
Amstelveen, KLM Hoofdkantoor	Amstelveen - KLM Hoofdkantoor	26	745	31%	1182	3	Leisure/Shopping	2	2	50%	50%	Unclear
Amstelveen, Molenweg	Amstelveen - Molenweg	27	606	25%	1185	3	Residential	0	0	0%	0%	Unclear
Amstelveen, Jan Benninghstraat	Amstelveen - Jan Benninghstraat	28	196	8%	1182	3	Leisure/Shopping	0	1	0%	100%	Egress
Amstelveen, Heemraadschapslaan	Amstelveen - Heemraadschapslaan	29	145	6%	1181	3	Residential	0	0	0%	0%	Unclear
Amstelveen, Busstation	Amstelveen - Busstation	30	930	39%	1185	3	Residential	2	4	33%	67%	Egress
TOTAAL			21928	29%						12%	14%	

Table 102: Classification of Stops of Line 187

Table 103: Stop Usage of Line 187

Average stop usage in March (%)		29%
Most used stop	Schiphol-rijk, Beechavenue	76%
Least used stop	Oude Meer, Hanger 9/10	0%

Line Performance

Commercial Timetable Speed and In-vehicle time

Table 104: Commercial speed of Line 187

Length of line	26,553
Timetable A to B (h)	44
Commercial time table speed	31
In-vehicle time (min)	19

Trip Cancelations

Table 105: Trip Cancelations of Line 187

# trips	2398
# cancelled	4
% cancelled	0,2%

Punctuality

Table 106: Average deviation from punctuality for all trips on line 187

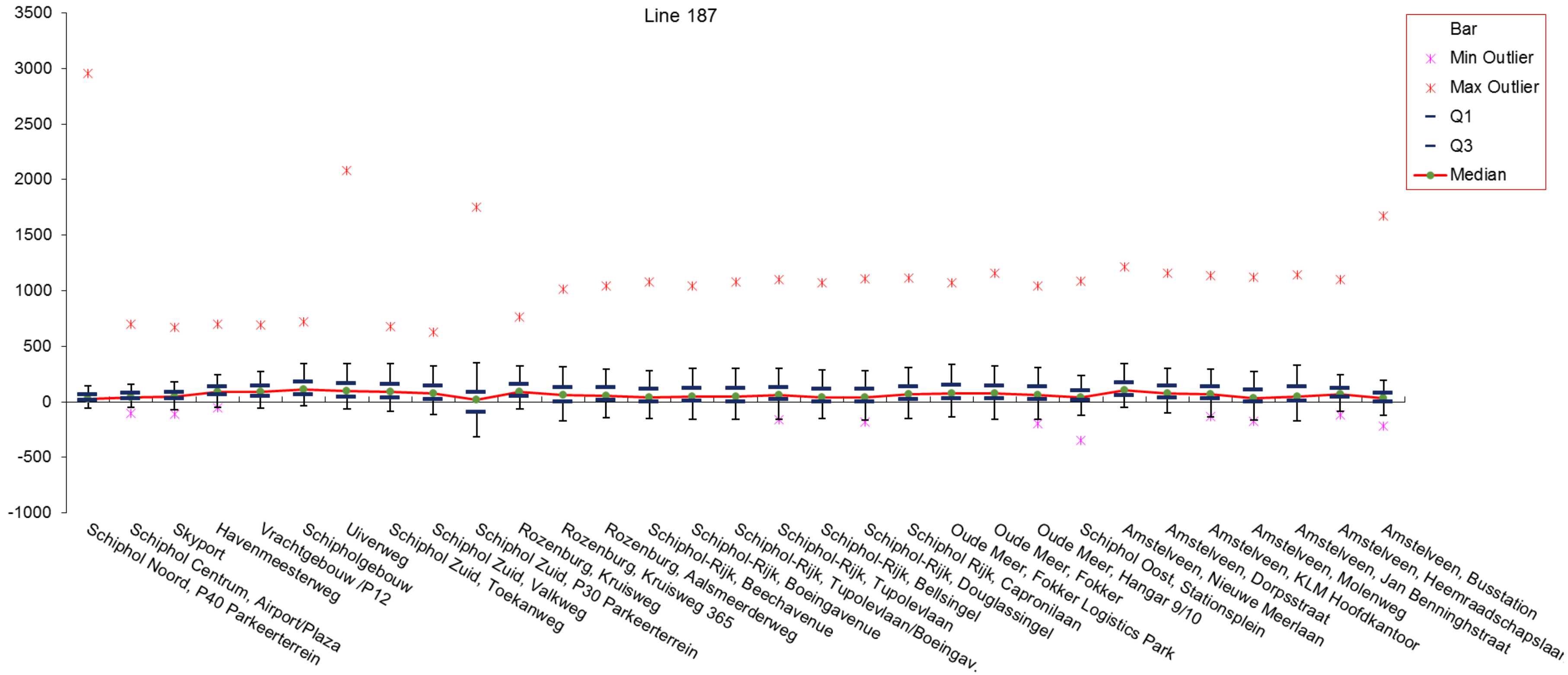
Parameter	Value
$n_{l,j}$ (#)	31
$n_{l,i}$ (#)	2398
p_l (s)	52

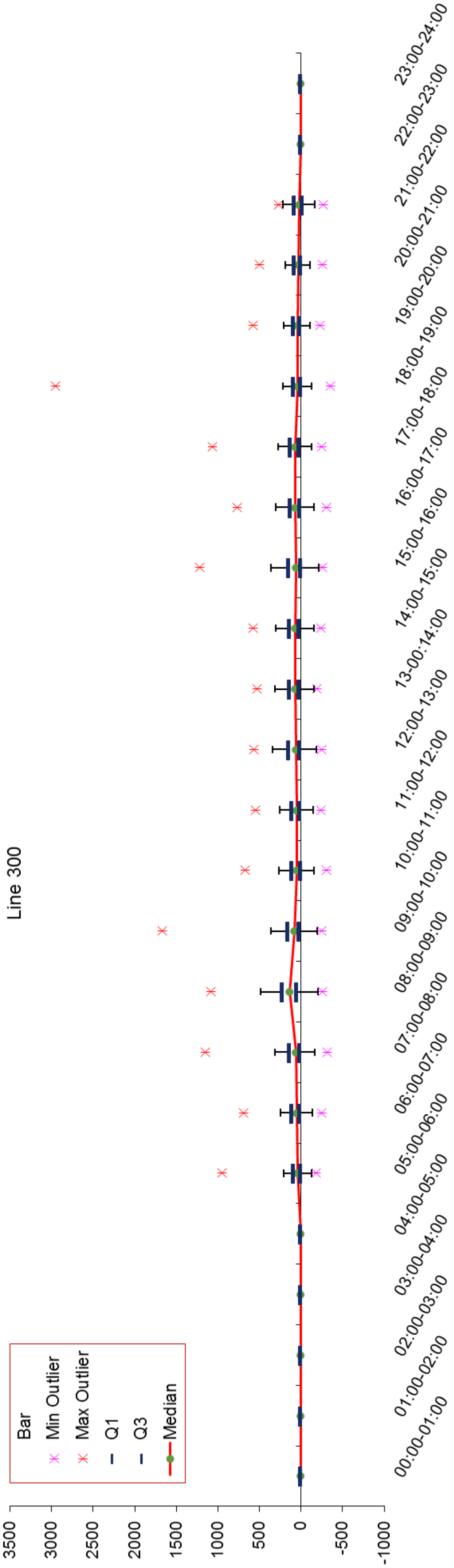
Table 107: Average deviation of too late/early departures on line 187

Parameter	Value
$n_{l,j}$ (#)	31
$n_{l,i}$ (#)	2398
p_l (s)	15

Table 108: Percentage of on-time departures of Line 187

# late/early	14299
Total	48115
% on time	70%


Line 187
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
Schiphol Noord, P40 Parkeerterrein
Schiphol Centrum, Airport/Plaza
Skyport
Havenmeesterweg
Vrachtgebouw /P12
Schipholgebouw
Uiverweg
Schiphol Zuid, Toekanweg
Schiphol Zuid, Valkweg
Schiphol Zuid, P30 Parkeerterrein
Rozenburg, Kruisweg
Rozenburg, Kruisweg 365
Rozenburg, Aalsmeerderweg
Schiphol-Rijk, Beechavenue
Schiphol-Rijk, Boeingavenue
Schiphol-Rijk, Tupolevlaan/Boeingav.
Schiphol-Rijk, Tupolevlaan
Schiphol-Rijk, Bellsingel
Schiphol-Rijk, Douglassingel
Schiphol Rijk, Capronilaan
Oude Meer, Fokker Logistics Park
Oude Meer, Fokker
Oude Meer, Hangar 9/10
Schiphol Oost, Stationsplein
Amstelveen, Nieuwe Meerlaan
Amstelveen, Dorpsstraat
Amstelveen, KLM Hoofdkantoor
Amstelveen, Molenweg
Amstelveen, Jan Benninghstraat
Amstelveen, Heemraadschapslaan
Amstelveen, Busstation



Line 300
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
00:00-01:00
01:00-02:00
02:00-03:00
03:00-04:00
04:00-05:00
05:00-06:00
06:00-07:00
07:00-08:00
08:00-09:00
09:00-10:00
10:00-11:00
11:00-12:00
12:00-13:00
13:00-14:00
14:00-15:00
15:00-16:00
16:00-17:00
17:00-18:00
18:00-19:00
19:00-20:00
20:00-21:00
21:00-22:00
22:00-23:00
23:00-24:00

G.6 R-Net – Line 300

Bus line 300 is a bus line in Amstelland-Meerlanden, and is a R-Net line. The route of this bus line goes from Lisse to Hoofddorp. Figure XX presents this route in the concession area Amstelland-Meerlanden.

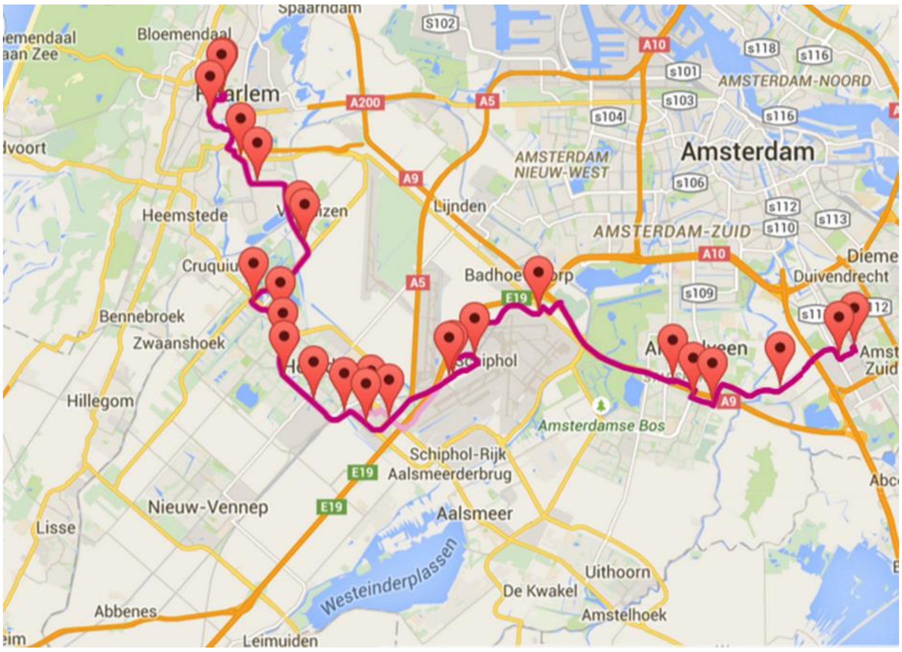


Figure 65: Route of Line 300 (Connexxion, 2015)

General Line Information

End Stop 1	Amsterdam, Bijlmer Arena
End Stop 2	Haarlem, Station
Frequency peak-hour (times/hour)	10
Frequency off-peak hour (times/hour)	10
Total number of stops (#)	26
Length (km)	41,679
Stop density (stops/km)	0,62
Average stop distance (km)	1,60
Dedicated infrastructure (km)	34,600
Dedicated infrastructure (% of total route)	83%
Number of bus trips (# in March)	10179
Number of passengers (#/week-day)	27300

Table 109: General Information of Line 300

Survey Information

Number of passengers (#/week-day)	27300
Number of usable survey responses	104
Confidence interval	95%
Margin of Error	9,59%

Table 110: Survey Information of Line 300

Access and Egress Modalities

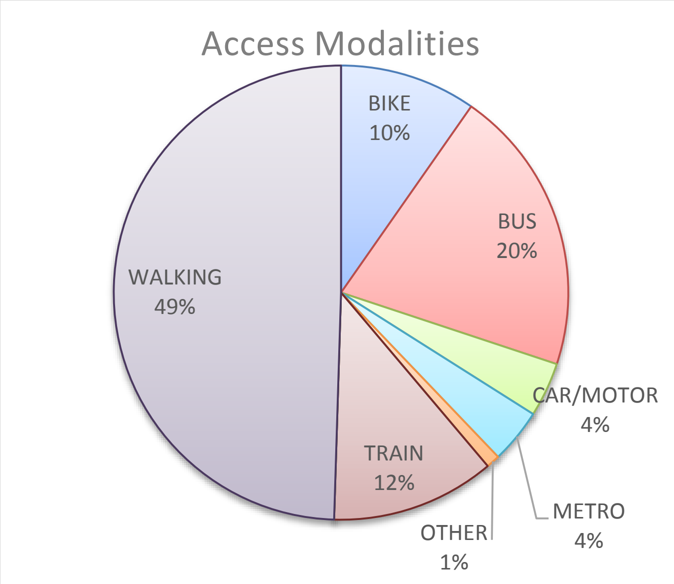


Figure 66: Access Modalities of Line 300

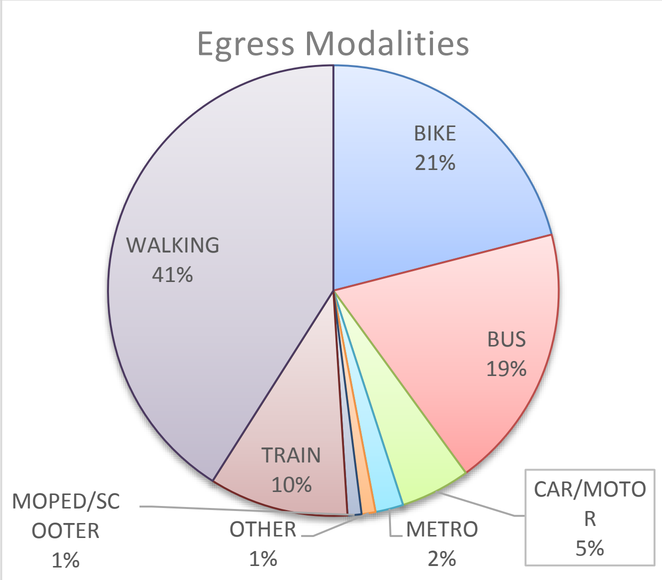


Figure 67: Egress Modalities of Line 300

Modality	Access	%	Egress	
BIKE	10	10%	21	21%
BUS	21	20%	19	19%
CAR/MOTOR	4	4%	5	5%
E-BIKE	0	0%	0	0%
METRO	4	4%	2	2%
OTHER	1	1%	1	1%
MOPED/SCOOTER	0	0%	1	1%
TRAIN	12	12%	10	10%
TRAM	0	0%	0	0%
WALKING	51	50%	41	41%
TOTAL	103	100%	100	100%

Table 111: Access and Egress Modalities for Line 300

Catchment Stop

Table 112: Catchment Area (distance in kilometres) of Bus Stops on Line 300

Access	Min	P25	MED	P75	MAX
Bike	0,665	0,961	1,211	1,957	2,120
Walk	0,132	0,706	1,033	1,369	5,370
Egress	Min	P25	MED	P75	MAX
Bike	0,2518	1,1512	1,3691	1,6587	5,0508
Walk	0,1317	0,5204	0,7060	1,0534	3,7608

Table 113: Catchment Area (travel time in minutes) of Bus Stops on Line 300

Access	Min	P25	MED	P75	MAX
Bike	0:02:00	0:02:53	0:03:38	0:05:52	0:06:22
Walk	0:01:35	0:08:28	0:12:24	0:16:26	1:04:26
Egress	Min	P25	MED	P75	MAX

Bike	0:00:45	0:03:27	0:04:06	0:04:59	0:15:09
Walk	0:01:35	0:06:15	0:08:28	0:12:38	0:45:08

Stop Performance

Stop Density

$$Stop\ Density = \frac{\#number\ of\ stops}{line\ lenght} = \frac{26}{41{,}679} = 0{,}62\ {}^{stops}/_{km}$$

Waiting time

Table 114: Waiting Times of Line 300

	Peak Hour	Off-Peak
Frequency (busses/hour)	10	10
Max Waiting time (minutes)	6	6

Classification of Stops

Stop		Number	# stops	% stop (usage)	postal code	Spatial	Activities	#access	#egress	% access	% egress	Stop type
Amsterdam, Bijlmer ArenA	Amsterdam - Bijlmer ArenA	1	7235	71%	1101	3	Work/Education	11	10	52%	48%	Access
Amsterdam, Holterbergweg	Amsterdam - Holterbergweg	2	4837	48%	1101	3	Work/Education	1	0	100%	0%	Access
Ouderkerk a/d Amstel	Ouderkerk a/d Amstel - J. van Ruisdae	3	7987	78%	1191	5	Residential	0	4	0%	100%	Egress
Amstelveen, Langerhuize	Amstelveen - Langerhuize	4	6279	62%	1184	5	Work/Education	3	2	60%	40%	Access
Amstelveen, Ouderkerkerlaan	Amstelveen - Ouderkerkerlaan	5	9512	93%	1185	2	Residential	6	2	75%	25%	Access
Amstelveen, Busstation	Amstelveen - Busstation	6	9507	93%	1185	2	Residential	8	13	38%	62%	Egress
Schiphol Noord, Cateringweg	Schiphol Noord - Cateringweg	7	9200	90%	1117	3	Work/Education	0	1	0%	100%	Egress
Schiphol Noord, Knooppunt Schiphol	Schiphol Noord - Knooppunt Schiphol	8	3056	30%	1171	3	Residential	0	1	0%	100%	Egress
Schiphol Noord, Elzenhof	Schiphol Noord - Elzenhof	9	4323	42%	1171	3	Residential	0	2	0%	100%	Egress
Schiphol Centrum, Airport/Plaza	Schiphol Centrum - Airport/Plaza	10	9466	93%	1118	5	Work/Education	17	14	55%	45%	Access
Schiphol Centrum, Handelskade	Schiphol Centrum - Handelskade	11	6772	67%	1118	5	Work/Education	2	1	67%	33%	Access
De Hoek, De Hoek	De Hoek - De Hoek	12	9566	94%	1437	3	Work/Education	4	5	44%	56%	Egress
Hoofddorp, Beukenhorst	Hoofddorp - Beukenhorst	13	4683	46%	2132	3	Work/Education	2	0	100%	0%	Access
Hoofddorp, Station	Hoofddorp - Station	14	9636	95%	2132	3	Work/Education	1	2	33%	67%	Egress
Hoofddorp, Graan voor Visch	Hoofddorp - Graan voor Visch	15	8927	88%	2132	3	Work/Education	8	7	53%	47%	Access
Hoofddorp, Toolenburg	Hoofddorp - Toolenburg	16	8725	86%	2135	3	Residential	1	4	20%	80%	Egress
Hoofddorp, Bornholm	Hoofddorp - Bornholm	17	8684	85%	2133	2	Residential	2	1	67%	33%	Access
Hoofddorp, Overbos	Hoofddorp - Overbos	18	8161	80%	2133	2	Residential	0	3	0%	100%	Egress
Hoofddorp, Spaarne Ziekenhuis	Hoofddorp - Spaarne Ziekenhuis	19	9477	93%	2134	2	Mixed	10	5	67%	33%	Access
Vijfhuizen, Vijfhuizen	Vijfhuizen - Vijfhuizen	20	7435	73%	2141	4	Mixed	0	3	0%	100%	Egress
Hoofddorp, Expo Haarlemmermeer	Hoofddorp - Expo Haarlemmermeer	21	722	7%	2141	4	Mixed	0	0	0%	0%	Unclear
Haarlem, Schalkwijk Centrum	Haarlem - Schalkwijk Centrum	22	9101	89%	2035	1	Mixed	3	3	50%	50%	Unclear
Haarlem, Europaweg	Haarlem - Europaweg	23	8608	85%	2034	1	Mixed	2	2	50%	50%	Unclear
Haarlem, Centrum/Verwulft	Haarlem - Centrum/Verwulft	24	9038	89%	2019	1	Mixed	5	9	36%	64%	Egress
Haarlem, Station ingang	Haarlem - Station ingang	25	2737	27%	2021	1	Mixed	0	0	0%	0%	Unclear
Haarlem, Station	Haarlem - Station	26	7451	73%	2021	1	Mixed	11	6	65%	35%	Access
TOTAAL			191125	72%						40%	53%	

Table 115: Classification of Stops of Line 300

Table 116: Stop Usage of Line 300

Average stop usage in March (%)		72%
Most used stop	Hoofddorp, Station	76
Least used stop	Hoofddorp, Expo Haarlemmermeer	7%

Line Performance

Commercial Timetable Speed and In-vehicle time

Table 117: Commercial speed of Line 300

Length of line	41,679
Timetable A to B (h)	68
Commercial time table speed	37
In-vehicle time (min)	16

Trip Cancelations

Table 118: Trip Cancelations of Line 300

# trips	10179
# cancelled	9
% cancelled	0,1%

Punctuality

Table 119: Average deviation from punctuality for all trips on line 300

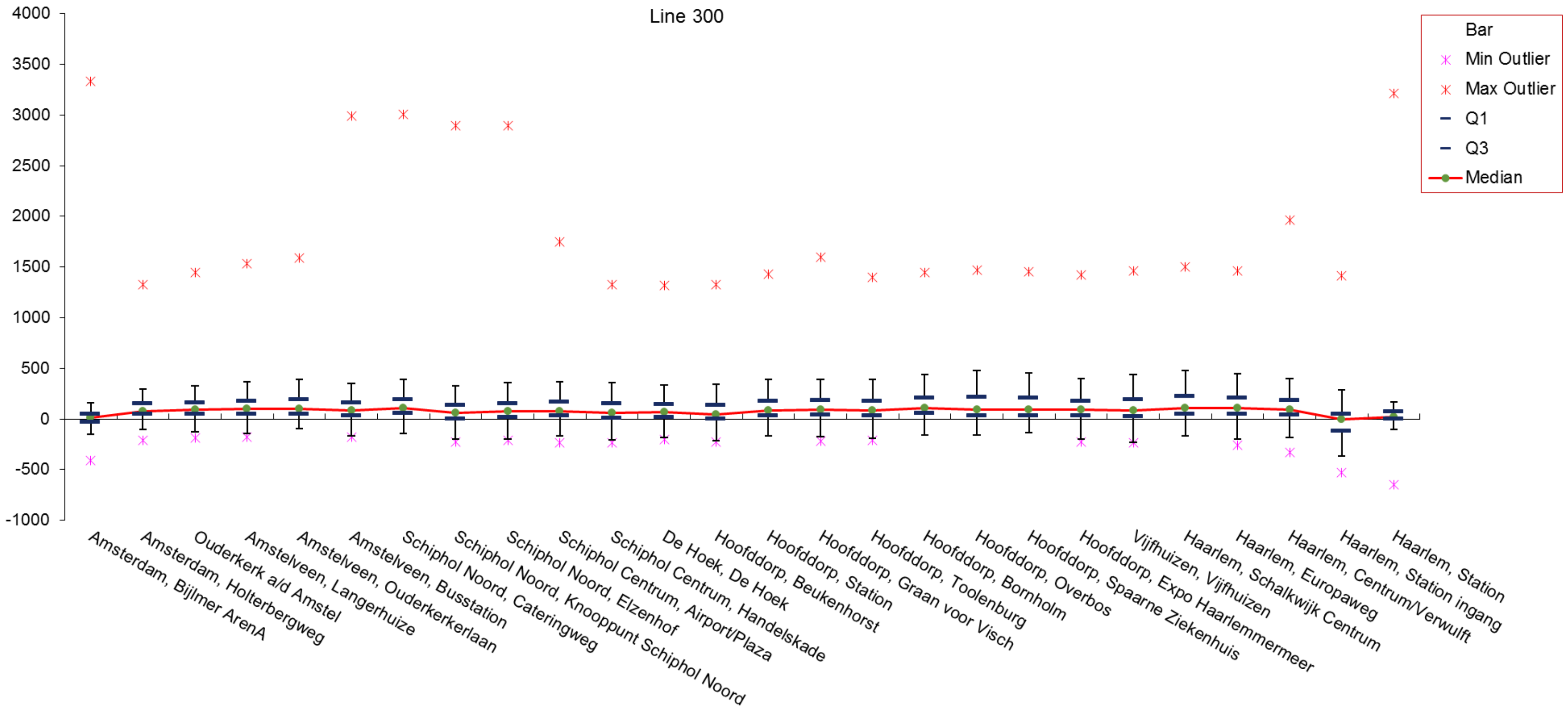
Parameter	Value
$n_{l,j}$ (#)	26
$n_{l,i}$ (#)	7885
p_l (s)	106

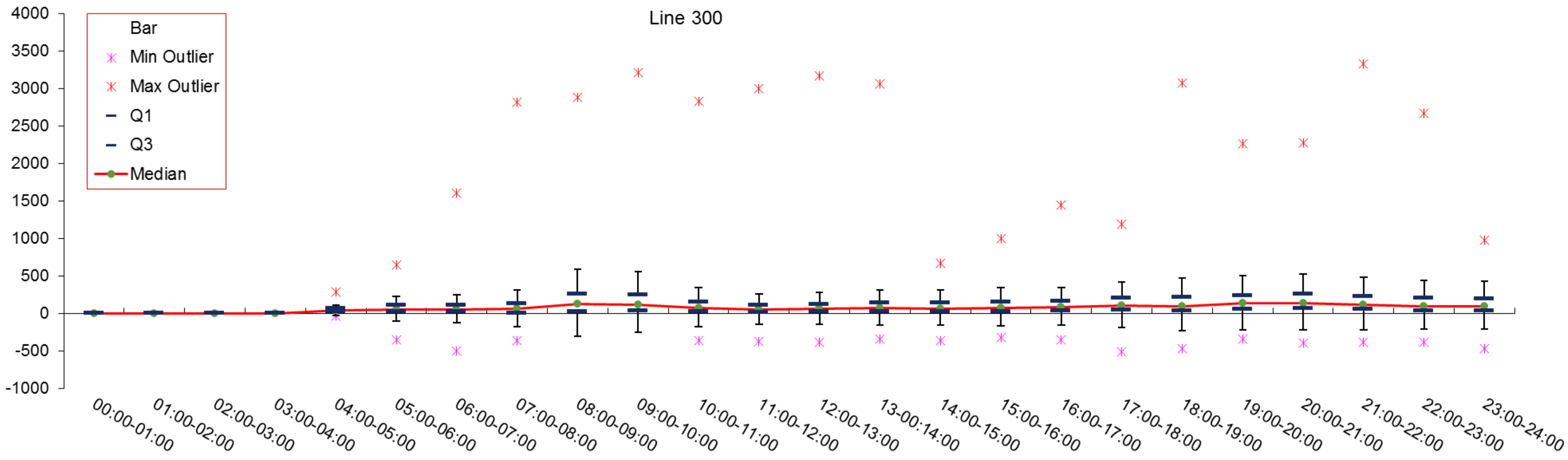
Table 120: Average deviation of too late/early departures on line 300

Parameter	Value
$n_{l,j}$ (#)	26
$n_{l,i}$ (#)	7885
p_l (s)	34

Table 121: Percentage of on-time departures of Line 300

# late/early	65483
Total	198346
% on time	67%


Line 300
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
Amsterdam, Bijlmer ArenA
Amsterdam, Holterbergweg
Ouderkerk a/d Amstel
Amstelveen, Langerhuize
Amstelveen, Ouderkerkerlaan
Amstelveen, Busstation
Schiphol Noord, Cateringweg
Schiphol Noord, Knooppunt Schiphol Noord
Schiphol Noord, Elzenhof
Schiphol Centrum, Airport/Plaza
Schiphol Centrum, Handelskade
De Hoek, De Hoek
Hoofddorp, Beukenhorst
Hoofddorp, Station
Hoofddorp, Graan voor Visch
Hoofddorp, Toolenburg
Hoofddorp, Bornholm
Hoofddorp, Overbos
Hoofddorp, Spaarne Ziekenhuis
Hoofddorp, Expo Haarlemmermeer
Vijfhuizen, Vijfhuizen
Haarlem, Schalkwijk Centrum
Haarlem, Europaweg
Haarlem, Centrum/Verwulft
Haarlem, Station ingang
Haarlem, Station


Line 300
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
00:00-01:00
01:00-02:00
02:00-03:00
03:00-04:00
04:00-05:00
05:00-06:00
06:00-07:00
07:00-08:00
08:00-09:00
09:00-10:00
10:00-11:00
11:00-12:00
12:00-13:00
13-00:14:00
14:00-15:00
15:00-16:00
16:00-17:00
17:00-18:00
18:00-19:00
19:00-20:00
20:00-21:00
21:00-22:00
22:00-23:00
23:00-24:00

G.7 R-Net – Line 310

Bus line 310 is a bus line in Amstelland-Meerlanden, and is a R-Net line. The route of this bus line goes from Lisse to Hoofddorp. Figure XX presents this route in the concession area Amstelland-Meerlanden. Half of the trips start or end at Schiphol Airport/Plaza, thus not all bus trips travel the entire route.

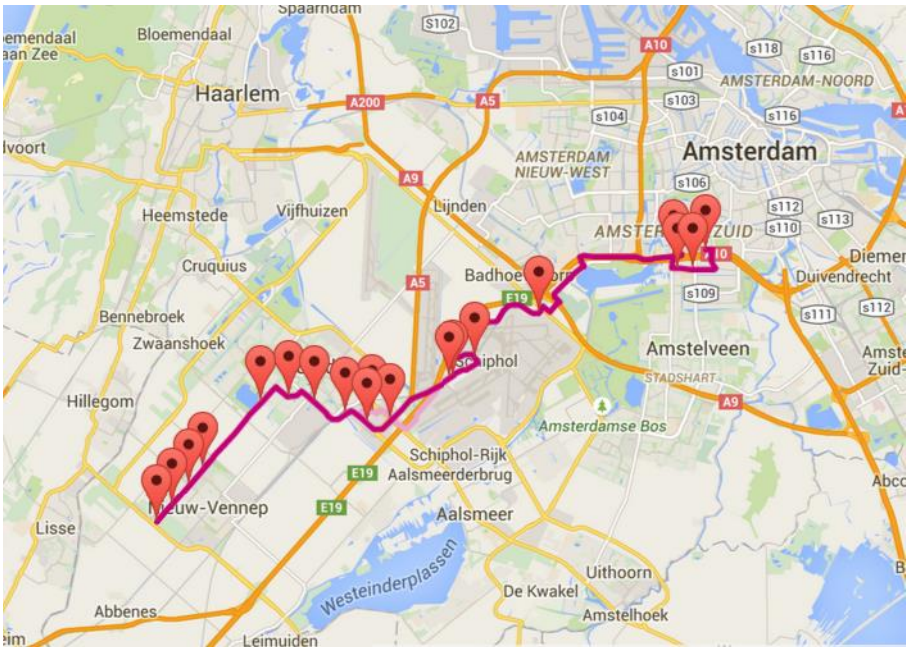


Figure 68: Route of Line 310 (Connexxion, 2015)

General Line Information

End Stop 1	Amsterdam, Station Zuid
End Stop 2	Nieuw-Vennep, Getsewoud P en R
Frequency peak-hour (times/hour)	10
Frequency off-peak hour (times/hour)	8
Total number of stops (#)	19
Length (km)	28,897
Stop density (stops/km)	0,66
Average stop distance (km)	1,52
Dedicated infrastructure (km)	20,750
Dedicated infrastructure (% of total route)	72%
Number of bus trips (# in March)	7136
Number of passengers (#/week-day)	7850

Table 122: General Information of Line 310

Survey Information

Number of passengers (#/week-day)	7850
Number of usable survey responses	74
Confidence interval	95%
Margin of Error	11,34%

Table 123: Survey Information of Line 310

Access and Egress Modalities

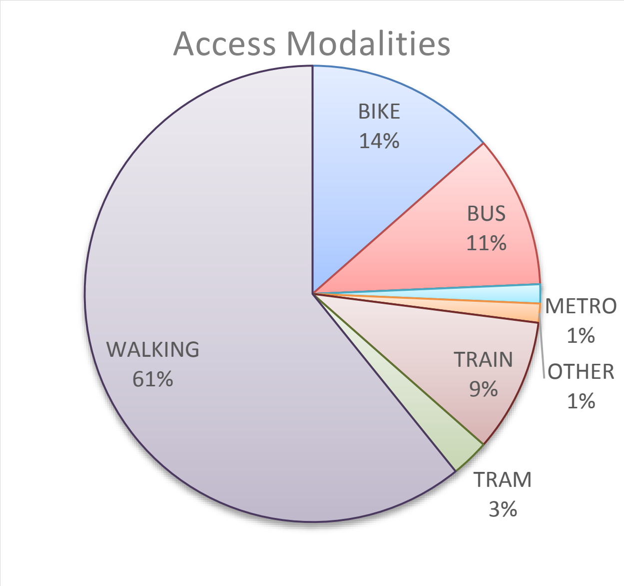


Figure 69: Access Modalities of Line 310

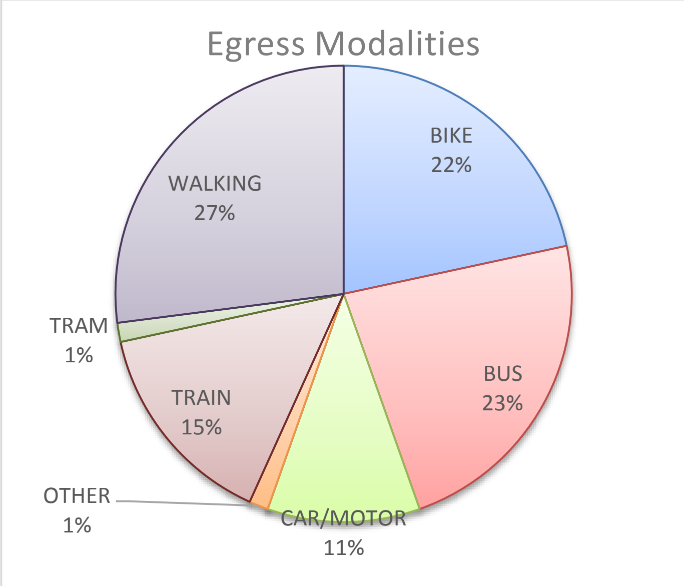


Figure 70: Egress Modalities of Line 310

Modality	Access	%	Egress	
BIKE	10	14%	16	22%
BUS	8	11%	17	23%
CAR/MOTOR	0	0%	8	11%
E-BIKE	0	0%	0	0%
METRO	1	1%	0	0%
OTHER	1	1%	1	1%
MOPED/SCOOTER	0	0%	0	0%
TRAIN	7	9%	11	15%
TRAM	2	3%	1	1%
WALKING	45	61%	20	27%
TOTAL	74	100%	74	100%

Table 124: Access and Egress Modalities for Line 310

Catchment Stop

Table 125: Catchment Area (distance in kilometres) of Bus Stops on Line 310

Access	Min	P25	MED	P75	MAX
Bike	0,272	0,473	0,613	1,008	3,631
Walk	0,265	0,786	0,891	1,193	2,180
Egress	Min	P25	MED	P75	MAX
Bike	0,2648	0,2648	0,4419	2,7723	3,7608
Walk	0,2648	0,3976	0,6613	0,9884	3,6311

Table 126: Catchment Area (travel time in minutes) of Bus Stops on Line 310

Access	Min	P25	MED	P75	MAX
Bike	0:00:49	0:01:25	0:01:50	0:03:01	0:10:54
Walk	0:03:11	0:09:26	0:10:42	0:14:19	0:26:09
Egress	Min	P25	MED	P75	MAX

Bike	0:00:48	0:00:48	0:01:20	0:08:19	0:11:17
Walk	0:03:11	0:04:46	0:07:56	0:11:52	0:43:34

Stop Performance

Stop Density

$$Stop\ Density = \frac{\#number\ of\ stops}{line\ lenght} = \frac{19}{28{,}897} = 0{,}66\ {}^{stops}/_{km}$$

Waiting time

Table 127: Waiting Times of Line 310

	Peak Hour	Off-Peak
Frequency (busses/hour)	10	8
Max Waiting time (minutes)	6	7,5

Classification of Stops

Stop		Number	# stops	% stop (usage)	postal code	Spatial	Activities	#access	#egress	% access	% egress	Stop type
Nieuw-Vennep, Getsewoud P en R	Nieuw-Vennep - Getsewoud P en R	1	5937	83%	2151	2	Residential	0	4	0%	100%	Egress
Nieuw-Vennep, Getsewoud Zuid	Nieuw-Vennep - Getsewoud Zuid	2	5281	74%	2151	2	Residential	3	2	60%	40%	Access
Nieuw-Vennep, Getsewoud Centrum	Nieuw-Vennep - Getsewoud Centrum	3	6858	96%	2152	3	Residential	7	6	54%	46%	Access
Nieuw-Vennep, Getsewoud Noord	Nieuw-Vennep - Getsewoud Noord	4	5947	83%	2152	3	Residential	2	11	15%	85%	Egress
Hoofddorp, Toolenburg Zuid	Hoofddorp - Toolenburg Zuid	5	4837	68%	2135	3	Residential	1	0	100%	0%	Access
Hoofddorp, Toolenburg Oost	Hoofddorp - Toolenburg Oost	6	6812	95%	2135	3	Residential	1	7	13%	88%	Egress
Hoofddorp, Graan voor Visch	Hoofddorp - Graan voor Visch	7	6181	87%	2132	3	Work/Education	4	6	40%	60%	Egress
Hoofddorp, Station	Hoofddorp - Station	8	6855	96%	2132	3	Work/Education	5	9	36%	64%	Egress
Hoofddorp, Beukenhorst	Hoofddorp - Beukenhorst	9	2541	36%	2132	3	Work/Education	5	1	83%	17%	Access
De Hoek, De Hoek	De Hoek - De Hoek	10	6825	96%	1437	3	Work/Education	1	0	100%	0%	Access
Schiphol Centrum, Handelskade	Schiphol Centrum - Handelskade	11	3853	54%	1118	5	Work/Education	0	0	0%	0%	Unclear
Schiphol Centrum, Airport/Plaza	Schiphol Centrum - Airport/Plaza	12	6090	85%	1118	5	Work/Education	10	15	40%	60%	Egress
Schiphol Noord, Elzenhof	Schiphol Noord - Elzenhof	13	932	13%	1171	3	Residential	1	0	100%	0%	Access
Schiphol Noord, Knooppunt Schiphol	Schiphol Noord - Knooppunt Schiphol	14	601	8%	1171	3	Residential	0	0	0%	0%	Unclear
Schiphol Noord, Cateringweg	Schiphol Noord - Cateringweg	15	2298	32%	1117	3	Work/Education	0	4	0%	100%	Egress
Amsterdam, Amstelveenseweg	Amsterdam - Amstelveenseweg	16	2341	33%	1076	1	Mixed	1	4	20%	80%	Egress
Amsterdam, VU Medisch Centrum	Amsterdam - VU Medisch Centrum	17	1955	27%	1081	1	Work/Education	10	1	91%	9%	Access
Amsterdam, De Boelelaan/VU	Amsterdam - De Boelelaan/VU	18	969	14%	1082	1	Residential	14	1	93%	7%	Access
Amsterdam, Station Zuid	Amsterdam - Station Zuid	19	1485	21%	1077	1	Residential	6	0	100%	0%	Access
TOTAAL			78598	58%						50%	40%	

Table 128: Classification of Stops of Line 310

Table 129: Stop Usage of Line 310

Average stop usage in March (%)		58%
Most used stop	Hoofddorp, Station	96%
Least used stop	Schiphol Noord, Knooppunt-Schiphol Noord	8%

Line Performance

Commercial Timetable Speed and In-vehicle time

Table 130: Commercial speed of Line 310

Length of line	28,897
Timetable A to B (h)	50
Commercial time table speed	35
In-vehicle time (min)	17

Trip Cancelations

Table 131: Trip Cancelations of Line 310

# trips	7136
# cancelled	14
% cancelled	0,2%

Punctuality

Table 132: Average deviation from punctuality for all trips on line 310

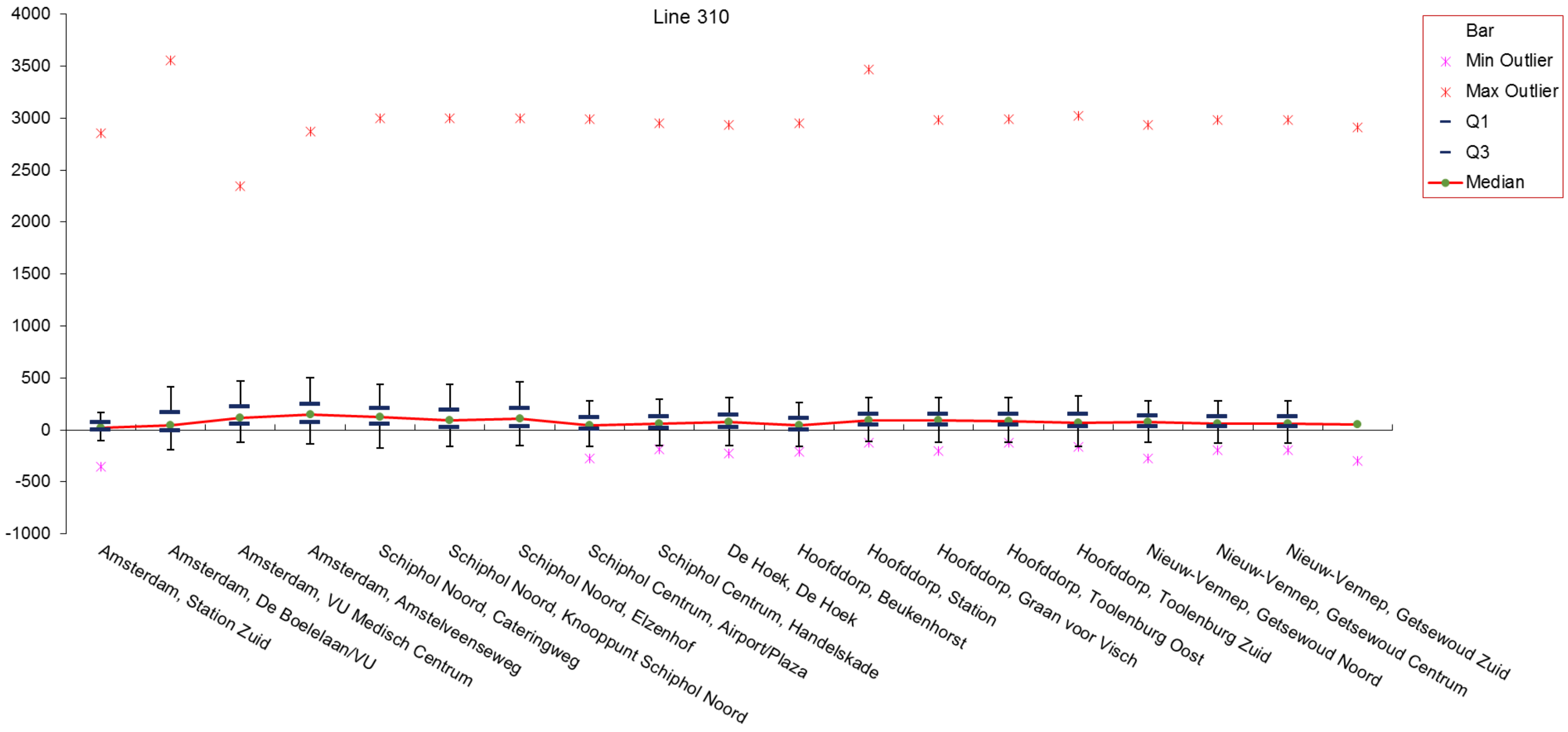
Parameter	Value
$n_{l,j}$ (#)	19
$n_{l,i}$ (#)	7136
p_l (s)	74

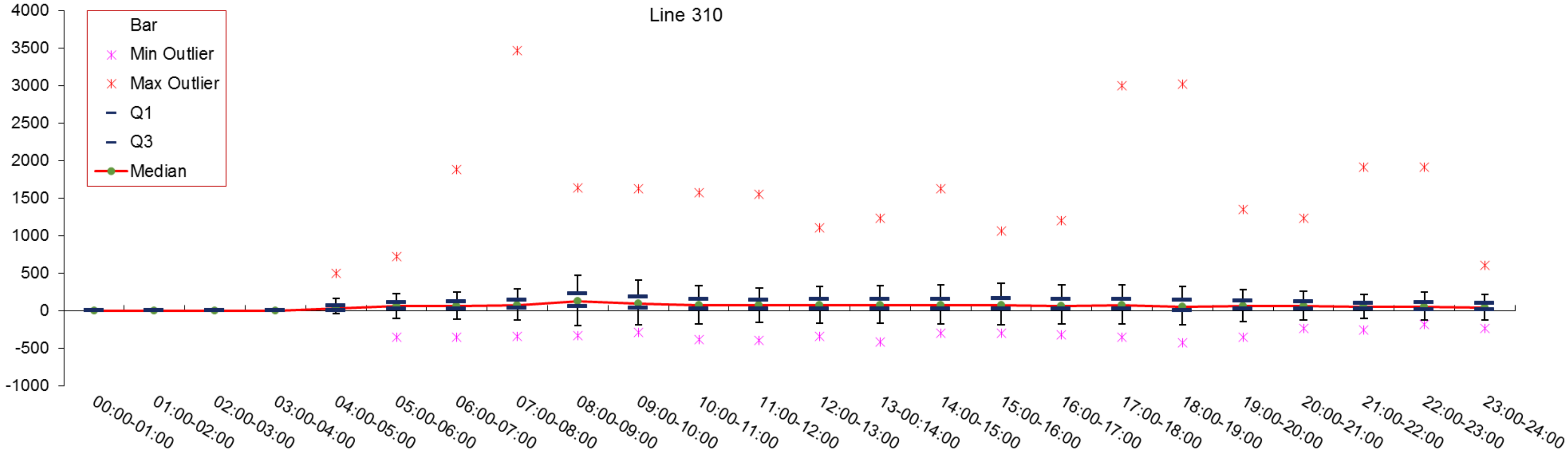
Table 133: Average deviation of too late/early departures on line 310

Parameter	Value
$n_{l,j}$ (#)	19
$n_{l,i}$ (#)	7136
p_l (s)	26

Table 134: Percentage of on-time departures of Line 310

# late/early	31515
Total	102727
% on time	69%


Line 310
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
Amsterdam, Station Zuid
Amsterdam, De Boelelaan/VU
Amsterdam, VU Medisch Centrum
Amsterdam, Amstelveenseweg
Schiphol Noord, Cateringweg
Schiphol Noord, Knooppunt Schiphol Noord
Schiphol Noord, Elzenhof
Schiphol Centrum, Airport/Plaza
Schiphol Centrum, Handelskade
De Hoek, De Hoek
Hoofddorp, Beukenhorst
Hoofddorp, Station
Hoofddorp, Graan voor Visch
Hoofddorp, Toolenburg Oost
Hoofddorp, Toolenburg Zuid
Nieuw-Vennep, Getsewoud Noord
Nieuw-Vennep, Getsewoud Centrum
Nieuw-Vennep, Getsewoud Zuid


Line 310
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
00:00-01:00
01:00-02:00
02:00-03:00
03:00-04:00
04:00-05:00
05:00-06:00
06:00-07:00
07:00-08:00
08:00-09:00
09:00-10:00
10:00-11:00
11:00-12:00
12:00-13:00
13-00:14:00
14:00-15:00
15:00-16:00
16:00-17:00
17:00-18:00
18:00-19:00
19:00-20:00
20:00-21:00
21:00-22:00
22:00-23:00
23:00-24:00

G.8 R-Net – Line 340

Bus line 340 is a bus line in Amstelland-Meerlanden, and is an R-Net line. The route of this bus line goes from Lisse to Hoofddorp. Figure XX presents this route in the concession area Amstelland-Meerlanden. Half of the trips start or end at Schiphol Airport/Plaza, thus not all bus trips travel the entire route.

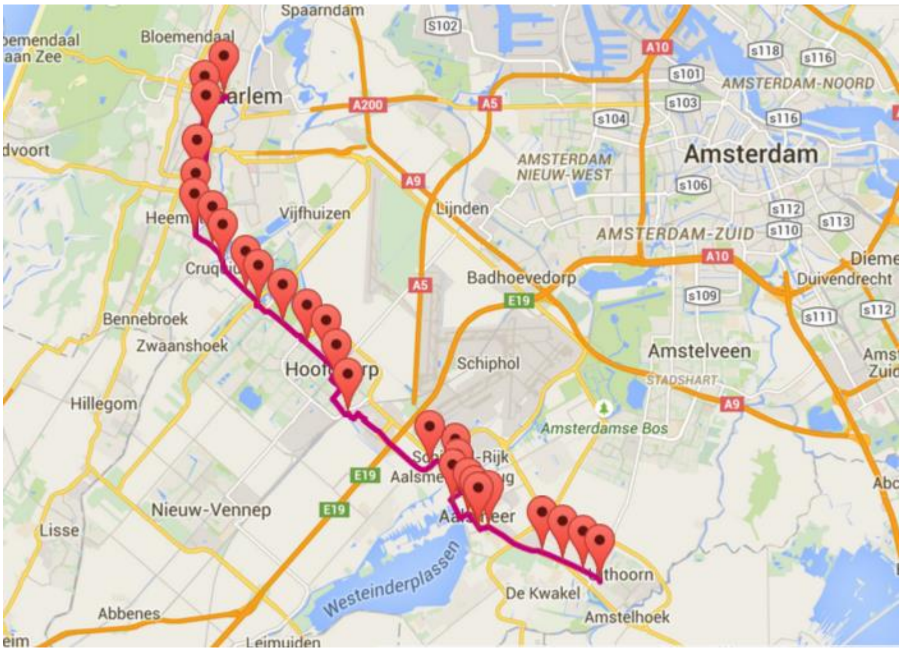


Figure 71: Route of Line 340 (Connexxion, 2015)

General Line Information

End Stop 1	Haarlem, Station
End Stop 2	Uithoorn, Busstation
Frequency peak-hour (times/hour)	8
Frequency off-peak hour (times/hour)	8
Total number of stops (#)	27
Length (km)	26,668
Stop density (stops/km)	1,0
Average stop distance (km)	0,99
Dedicated infrastructure (km)	9,300
Dedicated infrastructure (% of total route)	35%
Number of bus trips (# in March)	5690
Number of passengers (#/week-day)	7700

Table 135: General Information of Line 340

Survey Information

Number of passengers (#/week-day)	7700
Number of usable survey responses	63
Confidence interval	95%
Margin of Error	12,30%

Table 136: Survey Information of Line 340

Access and Egress Modalities

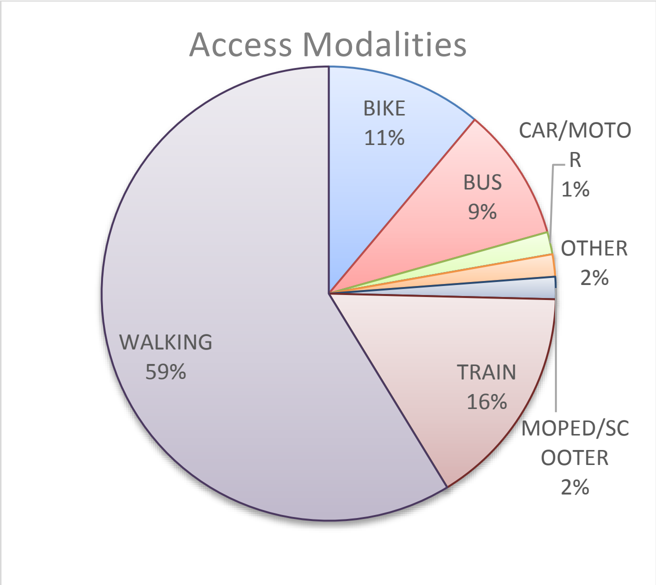


Figure 72: Access Modalities of Line 340

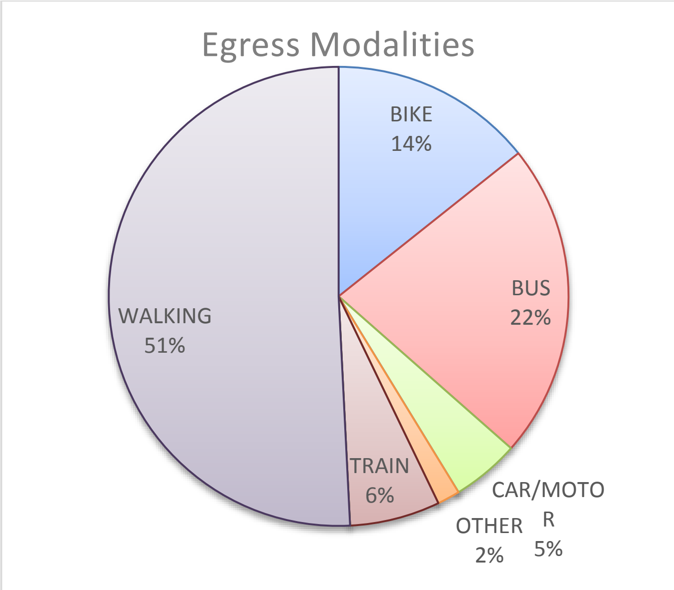


Figure 73: Egress Modalities of Line 340

Modality	Access	%	Egress	
BIKE	7	11%	9	14%
BUS	6	10%	14	22%
CAR/MOTOR	1	2%	3	5%
E-BIKE	0	0%	0	0%
METRO	0	0%	0	0%
OTHER	1	2%	1	2%
MOPED/SCOOTER	1	2%	0	0%
TRAIN	10	16%	4	6%
TRAM	0	0%	0	0%
WALKING	37	59%	32	51%
TOTAL	63	100%	63	100%

Table 137: Access and Egress Modalities for Line 340

Catchment Stop

Table 138: Catchment Area (distance in kilometres) of Bus Stops on Line 340

Access	Min	P25	MED	P75	MAX
Bike	0,244	0,413	0,890	1,795	3,073
Walk	0,194	0,469	0,710	0,919	2,358
Egress	Min	P25	MED	P75	MAX
Bike	0,0726	0,1785	0,9873	2,5356	3,5845
Walk	0,0726	0,4672	0,5259	1,0710	2,0741

Table 139: Catchment Area (travel time in minutes) of Bus Stops on Line 340

Access	Min	P25	MED	P75	MAX
Bike	0:00:44	0:01:14	0:02:40	0:05:23	0:09:13
Walk	0:02:20	0:05:38	0:08:31	0:11:01	0:28:18

Egress	Min	P25	MED	P75	MAX
Bike	0:00:13	0:00:32	0:02:58	0:07:36	0:10:45
Walk	0:00:52	0:05:36	0:06:19	0:12:51	0:24:53

Stop Performance

Stop Density

$$Stop\ Density = \frac{\#number\ of\ stops}{line\ lenght} = \frac{27}{26{,}668} = 1{,}01\ {}^{stops}/_{km}$$

Waiting time

Table 140: Waiting Times of Line 340

	Peak Hour	Off-Peak
Frequency (busses/hour)	8	8
Max Waiting time (minutes)	7,5	7,5

Classification of Stops

Stop		Number	# stops	% stop (usage)	postal code	Spatial	Activities	#access	#egress	% access	% egress	Stop type
Haarlem, Station	Haarlem - Station	1	4198	74%	2021	1	0	4	9	31%	69%	Egress
Haarlem, Raaksbrug	Haarlem - Raaksbrug	2	4428	78%	2013	1	0	1	2	33%	67%	Egress
Haarlem, Tempeliersstraat	Haarlem - Tempeliersstraat	3	5435	96%	2012	1	0	4	5	44%	56%	Egress
Heemstede, Blauwe Brug	Heemstede - Blauwe Brug	4	3618	64%	2102	2	0	2	2	50%	50%	Unclear
Heemstede, Julianaplein	Heemstede - Julianaplein	5	4132	73%	2101	2	0	0	1	0%	100%	Egress
Heemstede, Wipperplein	Heemstede - Wipperplein	6	5426	95%	2103	2	0	3	5	38%	63%	Egress
Heemstede, Cruquiusweg	Heemstede - Cruquiusweg	7	3456	61%	2103	2	0	2	1	67%	33%	Access
Cruquius, Ringvaartbrug	Cruquius - Ringvaartbrug	8	1885	33%	1171	3	Residential	0	0	0%	0%	Unclear
Cruquius, Spieringweg	Cruquius - Spieringweg	9	2666	47%	2142	5	Work/Education	4	0	100%	0%	Access
Hoofddorp, Spaarne Ziekenhuis	Hoofddorp - Spaarne Ziekenhuis	10	5458	96%	2134	2	Mixed	2	6	25%	75%	Egress
Hoofddorp, Overbos	Hoofddorp - Overbos	11	3899	69%	2133	2	Residential	0	2	0%	100%	Egress
Hoofddorp, Houtwijkerveld	Hoofddorp - Houtwijkerveld	12	3580	63%	2133	2	Residential	2	1	67%	33%	Access
Hoofddorp, RK Kerk	Hoofddorp - RK Kerk	13	4753	84%	2131	3	Residential	2	2	50%	50%	Unclear
Hoofddorp, Hoofddorp Centrum	Hoofddorp - Hoofddorp Centrum	14	5464	96%	2132	3	Work/Education	6	7	46%	54%	Egress
Hoofddorp, Station	Hoofddorp - Station	15	5450	96%	2132	3	Work/Education	12	5	71%	29%	Access
Rozenburg, SLP/Naritaweg	Rozenburg - SLP/Naritaweg	16	680	12%	1191	5	Residential	0	0	0%	0%	Unclear
Aalsmeer, Dorpsstraat	Aalsmeer - Dorpsstraat	17	2770	49%	1436	5	Residential	1	0	100%	0%	Access
Aalsmeer, van Cleeffkade	Aalsmeer - van Cleeffkade	18	2910	51%	1436	5	Residential	2	2	50%	50%	Unclear
Aalsmeer, Drie Kolommenplein	Aalsmeer - Drie Kolommenplein	19	2808	49%	1431	4	Mixed	0	1	0%	100%	Egress
Aalsmeer, Gloxiniastraat	Aalsmeer - Gloxiniastraat	20	1963	34%	1431	4	Mixed	1	0	100%	0%	Access
Aalsmeer, Hortensiaplein	Aalsmeer - Hortensiaplein	21	5398	95%	1431	4	Mixed	3	4	43%	57%	Egress
Aalsmeer, Zwarteweg	Aalsmeer - Zwarteweg	22	3609	63%	1431	4	Mixed	0	3	0%	100%	Egress
Aalsmeer, Zwarteweg/N196	Aalsmeer - Zwarteweg/N196	23	763	13%	1431	4	Mixed	0	0	0%	0%	Unclear
Uithoorn, Poelweg	Uithoorn - Poelweg	24	1249	22%	1424	3	Work/Education	1	0	100%	0%	Access
Uithoorn, Noorddammerweg	Uithoorn - Noorddammerweg	25	1777	31%	1422	3	Residential	0	0	0%	0%	Unclear
Uithoorn, Burg. Kootlaan	Uithoorn - Burg. Kootlaan	26	2454	43%	1422	3	Residential	4	0	100%	0%	Access
Uithoorn, Busstation	Uithoorn - Busstation	27	4375	77%	1422	3	Residential	5	4	56%	44%	Access
TOTAAL			94604	62%						43%	42%	

Table 141: Classification of Stops of Line 340

Table 142: Stop Usage of Line 340

Average stop usage in March (%)		62%
Most used stop	Hoofddorp, Hoofddorp Centrum Hoofddorp, Station	96%
Least used stop	Rozenburg, SLP/Naritaweg	12%

Line Performance

Commercial Timetable Speed and In-vehicle time

Table 143: Commercial speed of Line 340

Length of line	26.668
Timetable A to B (h)	59
Commercial time table speed	27
In-vehicle time (min)	22

Trip Cancelations

Table 144: Trip Cancelations of Line 340

# trips	5690
# cancelled	18
% cancelled	0,3%

Punctuality

Table 145: Average deviation from punctuality for all trips on line 340

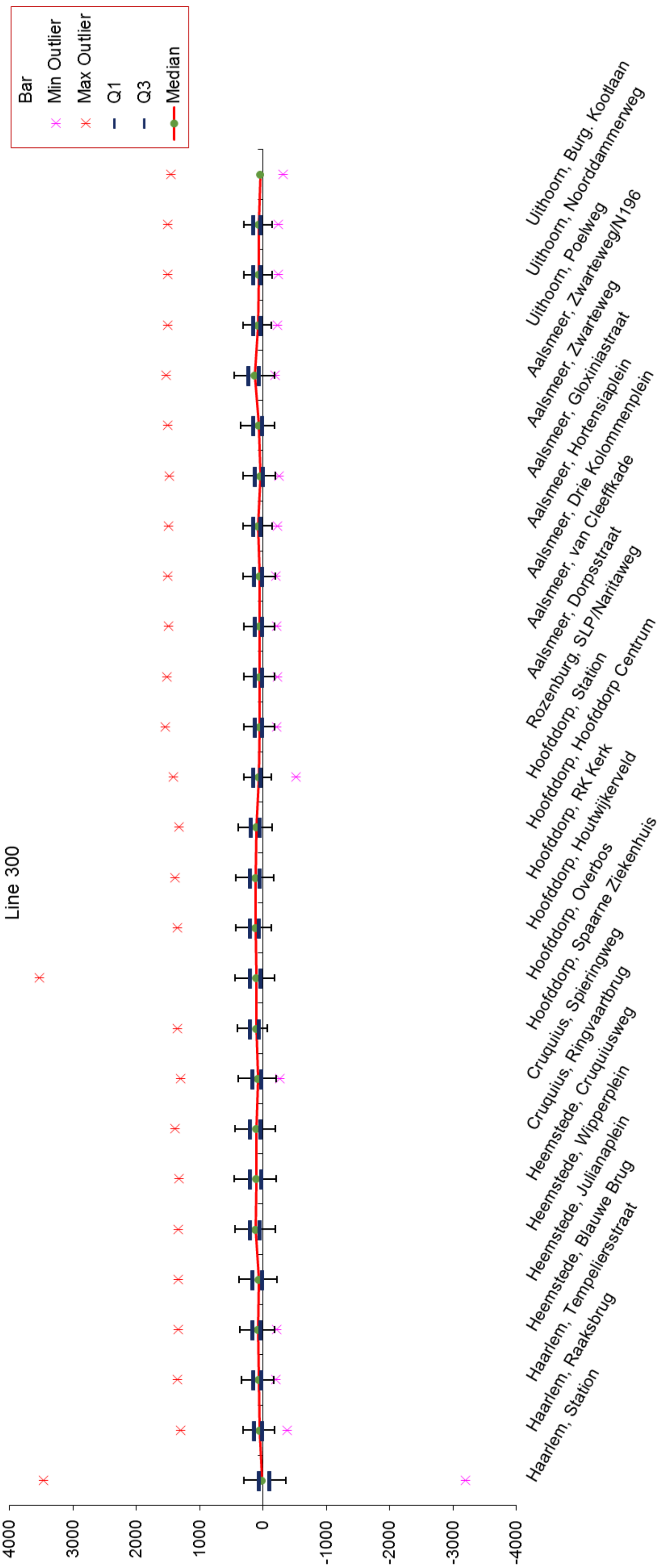
Parameter	Value
$n_{l,j}$ (#)	27
$n_{l,i}$ (#)	5690
p_l (s)	90

Table 146: Average deviation of too late/early departures on line 340

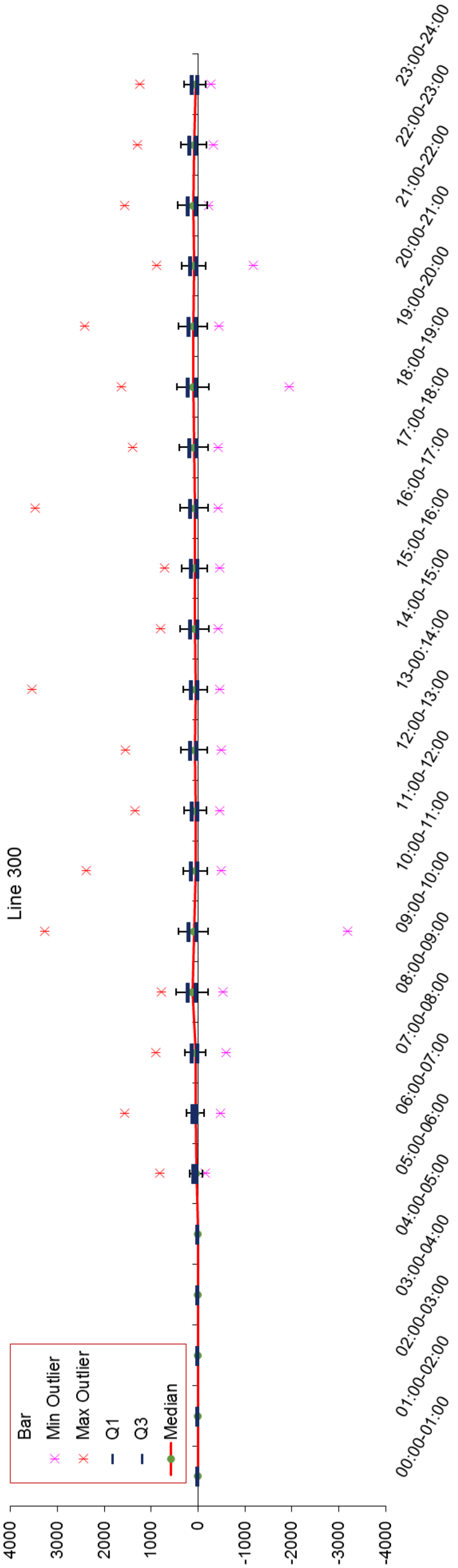
Parameter	Value
$n_{l,j}$ (#)	27
$n_{l,i}$ (#)	5690
p_l (s)	32

Table 147: Percentage of on-time departures of Line 340

# late/early	55370
Total	153631
% on time	64%



Line 300
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
Haarlem, Station
Haarlem, Raaksbrug
Haarlem, Tempeliersstraat
Heemstede, Blauwe Brug
Heemstede, Julianaplein
Heemstede, Wipperplein
Heemstede, Cruquiusweg
Cruquius, Ringvaartbrug
Cruquius, Spieringweg
Hoofddorp, Spaarne Ziekenhuis
Hoofddorp, Overbos
Hoofddorp, Houtwijkerveld
Hoofddorp, RK Kerk
Hoofddorp, Hoofddorp Centrum
Hoofddorp, Station
Rozenburg, SLP/Naritaweg
Aalsmeer, Dorpsstraat
Aalsmeer, van Cleeffkade
Aalsmeer, Drie Kolommenplein
Aalsmeer, Hortensiaplein
Aalsmeer, Gloxiniastraat
Aalsmeer, Zwarteweg
Aalsmeer, Zwarteweg/N196
Uithoorn, Poelweg
Uithoorn, Noorddammerweg
Uithoorn, Burg. Kootlaan



Line 300
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
00:00-01:00
01:00-02:00
02:00-03:00
03:00-04:00
04:00-05:00
05:00-06:00
06:00-07:00
07:00-08:00
08:00-09:00
09:00-10:00
10:00-11:00
11:00-12:00
12:00-13:00
13:00-14:00
14:00-15:00
15:00-16:00
16:00-17:00
17:00-18:00
18:00-19:00
19:00-20:00
20:00-21:00
21:00-22:00
22:00-23:00
23:00-24:00

G.9 R-Net – Line 346

Bus line 346 is a bus line in Amstelland-Meerlanden, and is an R-Net line. The route of this bus line goes from Lisse to Hoofddorp. Figure XX presents this route in the concession area Amstelland-Meerlanden. Half of the trips start or end at Schiphol Airport/Plaza, thus not all bus trips travel the entire route.

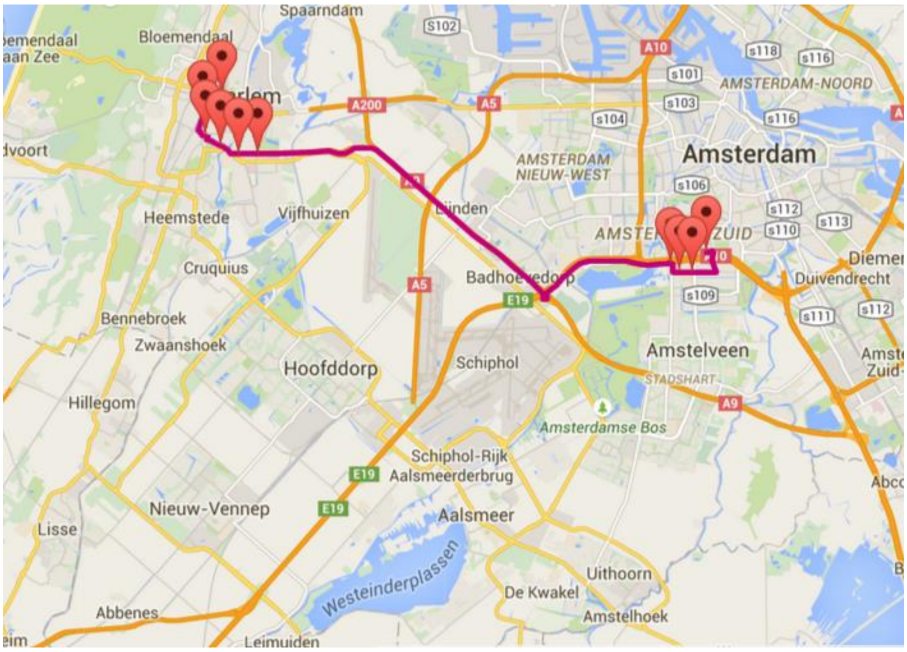


Figure 74: Route of Line 346 (Connexxion, 2015)

General Line Information

End Stop 1	Haarlem, Station
End Stop 2	Amsterdam, Station Zuid
Frequency peak-hour (times/hour)	11
Frequency off-peak hour (times/hour)	5
Total number of stops (#)	10
Length (km)	23,506
Stop density (stops/km)	0,42
Average stop distance (km)	2.35
Dedicated infrastructure (km)	3200
Dedicated infrastructure (% of total route)	14%
Number of bus trips (# in March)	4528
Number of passengers (#/week-day)	4300

Table 148: General Information of Line 346

Survey Information

Number of passengers (#/week-day)	4300
Number of usable survey responses	81
Confidence interval	95%
Margin of Error	10,79%

Table 149: Survey Information of Line 346

Access and Egress Modalities

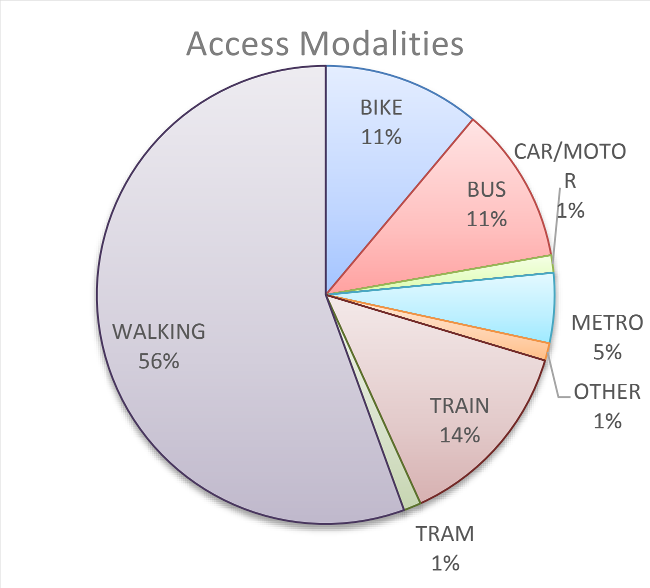


Figure 75: Access Modalities of Line 346

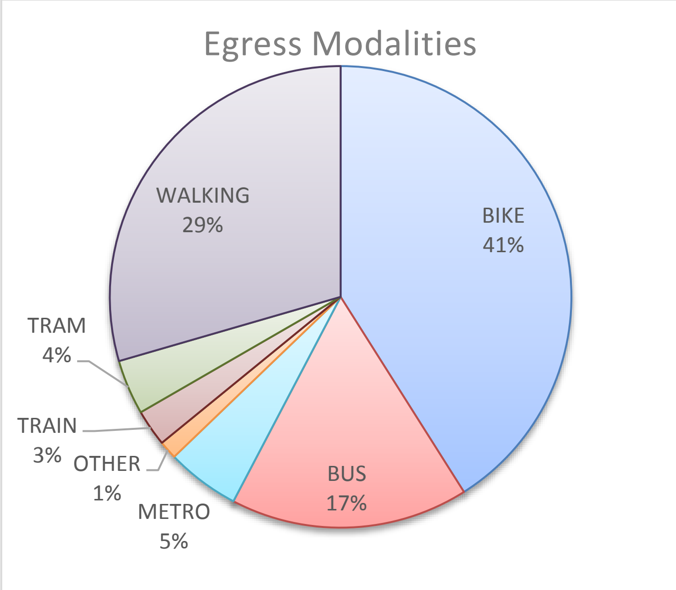


Figure 76: Egress Modalities of Line 346

Modality	Access	%	Egress	
BIKE	9	11%	32	41%
BUS	9	11%	13	17%
CAR/MOTOR	1	1%	0	0%
E-BIKE	0	0%	0	0%
METRO	4	5%	4	5%
OTHER	1	1%	1	1%
MOPED/SCOOTER	0	0%	0	0%
TRAIN	11	14%	2	3%
TRAM	1	1%	3	4%
WALKING	45	56%	23	29%
TOTAL	81	100%	78	100%

Table 150: Access and Egress Modalities for Line 346

Catchment Stop

Table 151: Catchment Area (distance in kilometres) of Bus Stops on Line 346

Access	Min	P25	MED	P75	MAX
Bike	0,621	0,860	1,090	1,655	2,074
Walk	0,498	0,731	0,830	0,891	1,667
Egress	Min	P25	MED	P75	MAX
Bike	0,3154	0,6972	1,2309	2,0250	5,3217
Walk	0,3154	0,5190	0,7859	0,8912	1,6889

Table 152: Catchment Area (travel time in minutes) of Bus Stops on Line 346

Access	Min	P25	MED	P75	MAX
Bike	0:01:52	0:02:35	0:03:16	0:04:58	0:06:13
Walk	0:05:59	0:08:46	0:09:57	0:10:42	0:20:01
Egress	Min	P25	MED	P75	MAX

Bike	0:00:57	0:02:05	0:03:42	0:06:05	0:15:58
Walk	0:03:47	0:06:14	0:09:26	0:10:42	0:20:16

Stop Performance

Stop Density

$$Stop\ Density = \frac{\#number\ of\ stops}{line\ lenght} = \frac{10}{23{,}506} = 0{,}42\ ^{stops}/_{km}$$

Waiting time

Table 153: Waiting Times of Line 346

	Peak Hour	Off-Peak
Frequency (busses/hour)	11	5
Max Waiting time (minutes)	5,5	12

Classification of Stops

Stop		Number	# stops	% stop (usage)	postal code	Spatial	Activities	#access	#egress	% access	% egress	Stop type
Amsterdam, Station Zuid	Amsterdam - Station Zuid	1	3599	79%	1077	1	Residential	11	4	73%	27%	Access
Amsterdam, De Boelelaan/VU	Amsterdam - De Boelelaan/VU	2	1944	43%	1082	1	Residential	17	9	65%	35%	Access
Amsterdam, VU Medisch Centrum	Amsterdam - VU Medisch Centrum	3	3530	78%	1081	1	Work/Education	12	6	67%	33%	Access
Amsterdam, Amstelveenseweg	Amsterdam - Amstelveenseweg	4	4384	97%	1076	1	Mixed	2	8	20%	80%	Egress
Haarlem, Schipholweg/Europaweg	Haarlem - Schipholweg/Europaweg	5	3564	79%	2033	2	0	2	5	29%	71%	Egress
Haarlem, Burg. Reinaldapark	Haarlem - Burg. Reinaldapark	6	3543	78%	2033	2	0	7	0	100%	0%	Access
Haarlem, Rustenburgerlaan	Haarlem - Rustenburgerlaan	7	3362	74%	2012	1	0	3	2	60%	40%	Access
Haarlem, Tempeliersstraat	Haarlem - Tempeliersstraat	8	4385	97%	2012	1	0	9	14	39%	61%	Egress
Haarlem, Raaksbrug	Haarlem - Raaksbrug	9	3728	82%	2013	1	0	3	8	27%	73%	Egress
Haarlem, Station ingang	Haarlem - Station ingang	10	1083	24%	2021	1	0	0	0	0%	0%	Unclear
Haarlem, Station	Haarlem - Station	11	2662	59%	2021	1	0	13	24	35%	65%	Egress
TOTAAL			35784	72%						47%	44%	

Table 154: Classification of Stops of Line 346

Table 155: Stop Usage of Line 346

Average stop usage in March (%)		62%
Most used stop	Amsterdam, Amstelveenseweg	97%
Least used stop	Amsterdam, De Boelelaan/VU	43%

Line Performance

Commercial Timetable Speed and In-vehicle time

Table 156: Commercial speed of Line 346

Length of line	23,506
Timetable A to B (h)	35
Commercial time table speed	40
In-vehicle time (min)	15

Trip Cancelations

Table 157: Trip Cancelations of Line 346

# trips	4528
# cancelled	8
% cancelled	0,2%

Punctuality

Table 158: Average deviation from punctuality for all trips on line 346

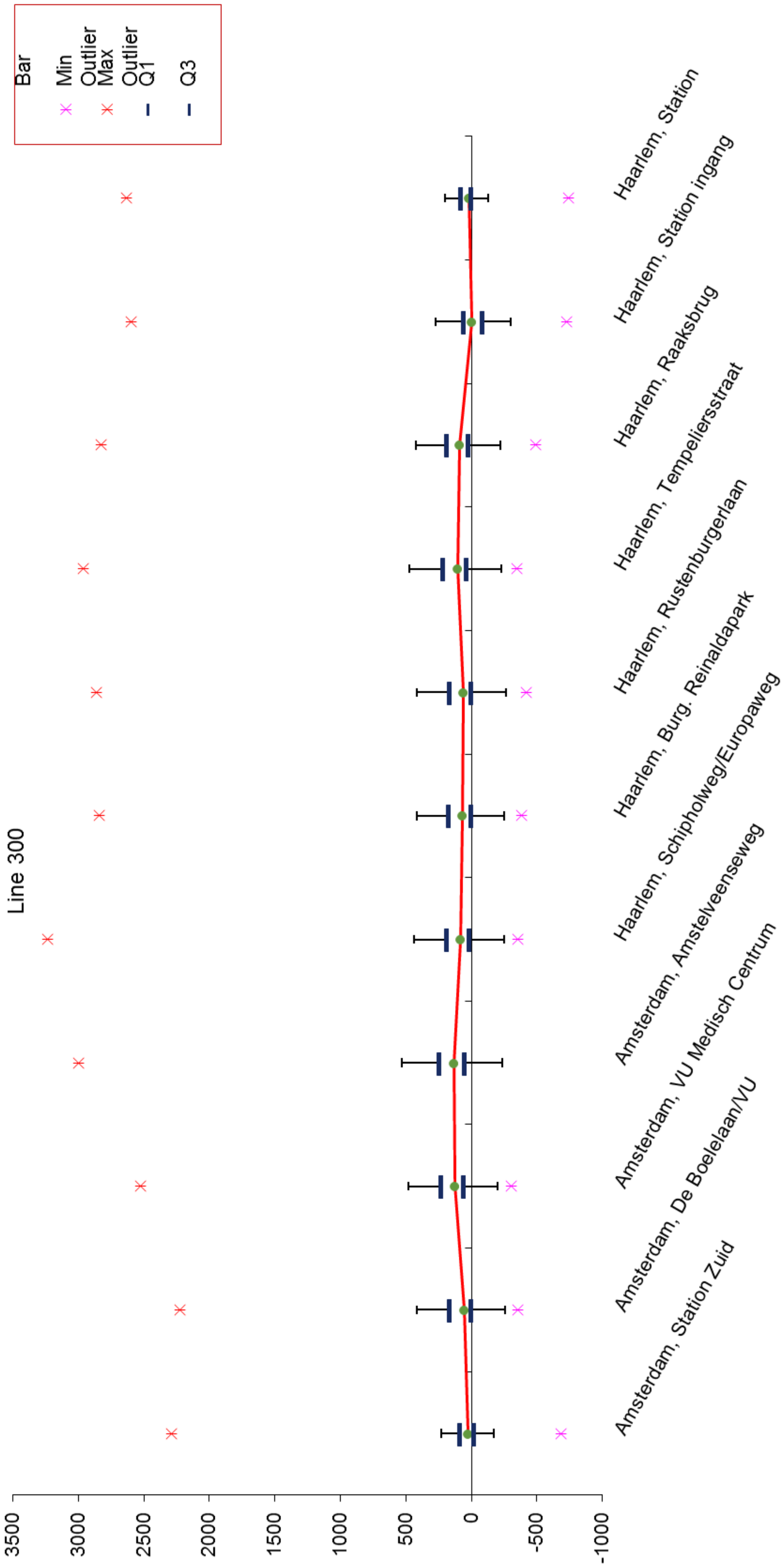
Parameter	Value
$n_{l,j}$ (#)	10
$n_{l,i}$ (#)	4528
p_l (s)	113

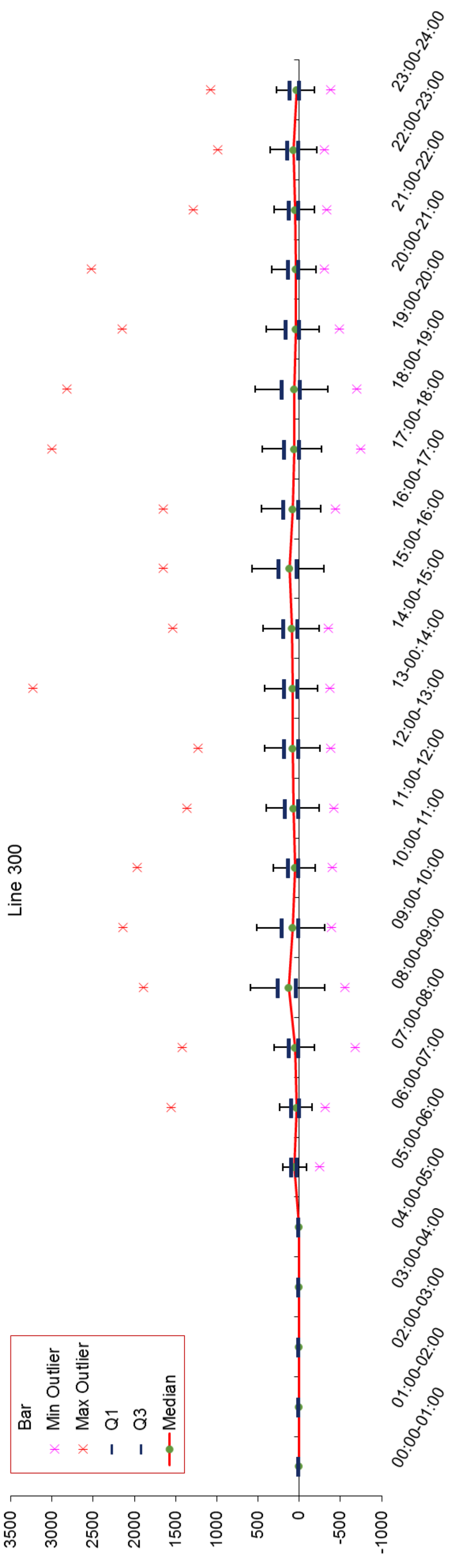
Table 159: Average deviation of too late/early departures on line 346

Parameter	Value
$n_{l,j}$ (#)	10
$n_{l,i}$ (#)	4528
p_l (s)	66

Table 160: Percentage of on-time departures of Line 346

# late/early	20764
Total	47521
% on time	56%


Line 300
Bar
Min
Outlier
Max
Outlier
Q1
Q3
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
Haarlem, Station
Haarlem, Station ingang
Haarlem, Raaksbrug
Haarlem, Tempeliersstraat
Haarlem, Rustenburgerlaan
Haarlem, Burg. Reinaldapark
Haarlem, Schipholweg/Europaweg
Amsterdam, Amstelveenseweg
Amsterdam, VU Medisch Centrum
Amsterdam, De Boelelaan/VU
Amsterdam, Station Zuid


Line 300
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
00:00-01:00
01:00-02:00
02:00-03:00
03:00-04:00
04:00-05:00
05:00-06:00
06:00-07:00
07:00-08:00
08:00-09:00
09:00-10:00
10:00-11:00
11:00-12:00
12:00-13:00
13-00:14:00
14:00-15:00
15:00-16:00
16:00-17:00
17:00-18:00
18:00-19:00
19:00-20:00
20:00-21:00
21:00-22:00
22:00-23:00
23:00-24:00

G.10 R-Net – Line 356

Bus line 356 is a bus line in Amstelland-Meerlanden, and is an R-Net line. The route of this bus line goes from Lisse to Hoofddorp. Figure XX presents this route in the concession area Amstelland-Meerlanden. Half of the trips start or end at Schiphol Airport/Plaza, thus not all bus trips travel the entire route.

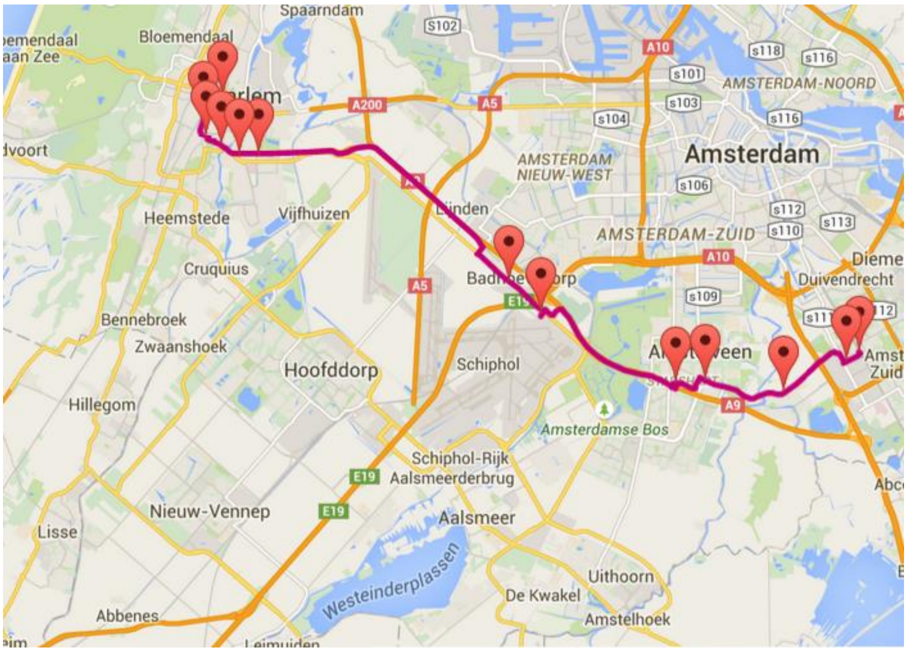


Figure 77: Route of Line 356 (Connexxion, 2015)

General Line Information

End Stop 1	Haarlem, Station
End Stop 2	Amsterdam, Bijlmer Arena
Frequency peak-hour (times/hour)	8
Frequency off-peak hour (times/hour)	4
Total number of stops (#)	14
Length (km)	30,647
Stop density (stops/km)	0,46
Average stop distance (km)	2,19
Dedicated infrastructure (km)	7,200
Dedicated infrastructure (% of total route)	23%
Number of bus trips (# in March)	4920
Number of passengers (#/week-day)	4200

Table 161: General Information of Line 356

Survey Information

Number of passengers (#/week-day)	4200
Number of usable survey responses	74
Confidence interval	95%
Margin of Error	10,30%

Table 162: Survey Information of Line 356

Access and Egress Modalities

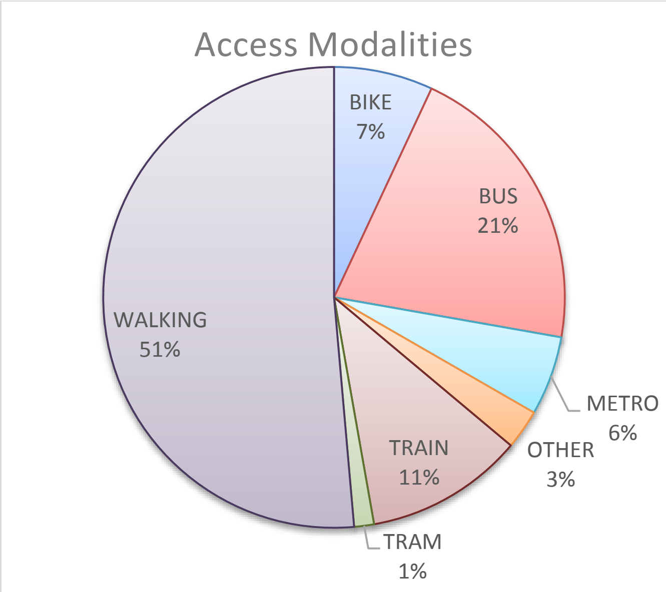


Figure 78: Access Modalities of Line 356

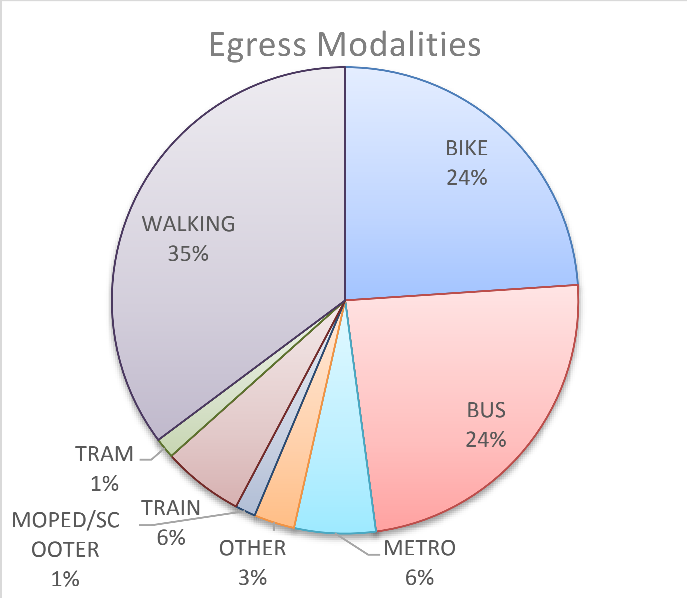


Figure 79: Egress Modalities of Line 356

Modality	Access	%	Egress	
BIKE	5	7%	17	24%
BUS	15	21%	17	24%
CAR/MOTOR	0	0%	0	0%
E-BIKE	0	0%	0	0%
METRO	4	6%	4	6%
OTHER	2	3%	2	3%
MOPED/SCOOTER	0	0%	1	1%
TRAIN	8	11%	4	6%
TRAM	1	1%	1	1%
WALKING	37	51%	25	35%
TOTAL	72	100%	71	100%

Table 163: Access and Egress Modalities for Line 356

Catchment Stop

Table 164: Catchment Area (distance in kilometres) of Bus Stops on Line 356

Access	Min	P25	MED	P75	MAX
Bike	0,830	1,309	2,074	2,596	3,118
Walk	0,228	0,356	0,644	0,780	1,216
Egress	Min	P25	MED	P75	MAX
Bike	0,3154	0,6701	0,8298	1,0331	3,1176
Walk	0,2277	0,6220	0,7181	1,0849	2,9859

Table 165: Catchment Area (travel time in minutes) of Bus Stops on Line 356

Access	Min	P25	MED	P75	MAX
Bike	0:02:29	0:03:56	0:06:13	0:07:47	0:09:21

Walk	0:02:44	0:04:16	0:07:43	0:09:22	0:14:36
Egress	Min	P25	MED	P75	MAX
Bike	0:00:57	0:02:01	0:02:29	0:03:06	0:09:21
Walk	0:02:44	0:07:28	0:08:37	0:13:01	0:35:50

Stop Performance

Stop Density

$$Stop\ Density = \frac{\#number\ of\ stops}{line\ lenght} = \frac{14}{30{,}647} = 0{,}46\ {}^{stops}/_{km}$$

Waiting time

Table 166: Waiting Times of Line 356

	Peak Hour	Off-Peak
Frequency (busses/hour)	8	4
Max Waiting time (minutes)	7,5	15

Classification of Stops

Stop		Number	# stops	% stop (usage)	postal code	Spatial	Activities	#access	#egress	% access	% egress	Stop type
Amsterdam, Bijlmer ArenA	Amsterdam - Bijlmer ArenA	1	2605	53%	1101	3	Work/Education	16	15	52%	48%	Access
Amsterdam, Holterbergweg	Amsterdam - Holterbergweg	2	1769	36%	1101	3	Work/Education	6	1	86%	14%	Access
Ouderkerk a/d Amstel, J. van Ruisdae	Ouderkerk a/d Amstel - J. van Ruisdae	3	2152	44%	1191	5	Residential	1	4	20%	80%	Egress
Amstelveen, Oranjebaan	Amstelveen - Oranjebaan	4	2967	60%	1183	2	Residential	6	3	67%	33%	Access
Amstelveen, Busstation	Amstelveen - Busstation	5	4300	87%	1185	2	Residential	8	14	36%	64%	Egress
Cateringweg	Schiphol Noord - Cateringweg	6	2130	43%	1117	3	Work/Education	0	2	0%	100%	Egress
Schiphol Noord, Knooppunt Schiphol	Schiphol Noord - Knooppunt Schiphol	7	2271	46%	1171	3	Residential	2	1	67%	33%	Access
Badhoevedorp, Badhoevedorp Oost	Badhoevedorp - Badhoevedorp Oost	8	3415	69%	1171	3	Residential	2	6	25%	75%	Egress
Haarlem, Burg. Reinaldapark	Haarlem - Burg. Reinaldapark	9	2797	57%	2033	2	0	1	4	20%	80%	Egress
Haarlem, Schipholweg/Europaweg	Haarlem - Schipholweg/Europaweg	10	2849	58%	2033	2	0	4	7	36%	64%	Egress
Haarlem, Rustenburgerlaan	Haarlem - Rustenburgerlaan	11	2669	54%	2012	1	0	2	2	50%	50%	Unclear
Haarlem, Tempeliersstraat	Haarlem - Tempeliersstraat	12	4525	92%	2012	1	0	4	5	44%	56%	Egress
Haarlem, Raaksbrug	Haarlem - Raaksbrug	13	3503	71%	2013	1	0	9	4	69%	31%	Access
Haarlem, Station ingang	Haarlem - Station ingang	14	1196	24%	2021	1	0	0	0	0%	0%	Unclear
Haarlem, Station	Haarlem - Station	15	3045	62%	2021	1	0	10	4	71%	29%	Access
TOTAAL			42193	57%						43%	50%	

Table 167: Classification of Stops of Line 356

Table 168: Stop Usage of Line 356

Average stop usage in March (%)		57%
Most used stop	Haarlem, Tempeliersstraat	92%
Least used stop	Amsterdam, Holterbergweg	36%

Line Performance

Commercial Timetable Speed and In-vehicle time

Table 169: Commercial speed of Line 356

Length of line	30,647
Timetable A to B (h)	49
Commercial time table speed	38
In-vehicle time (min)	16

Trip Cancelations

Table 170: Trip Cancelations of Line 356

# trips	4920
# cancelled	6
% cancelled	0,1%

Punctuality

Table 171: Average deviation from punctuality for all trips on line 356

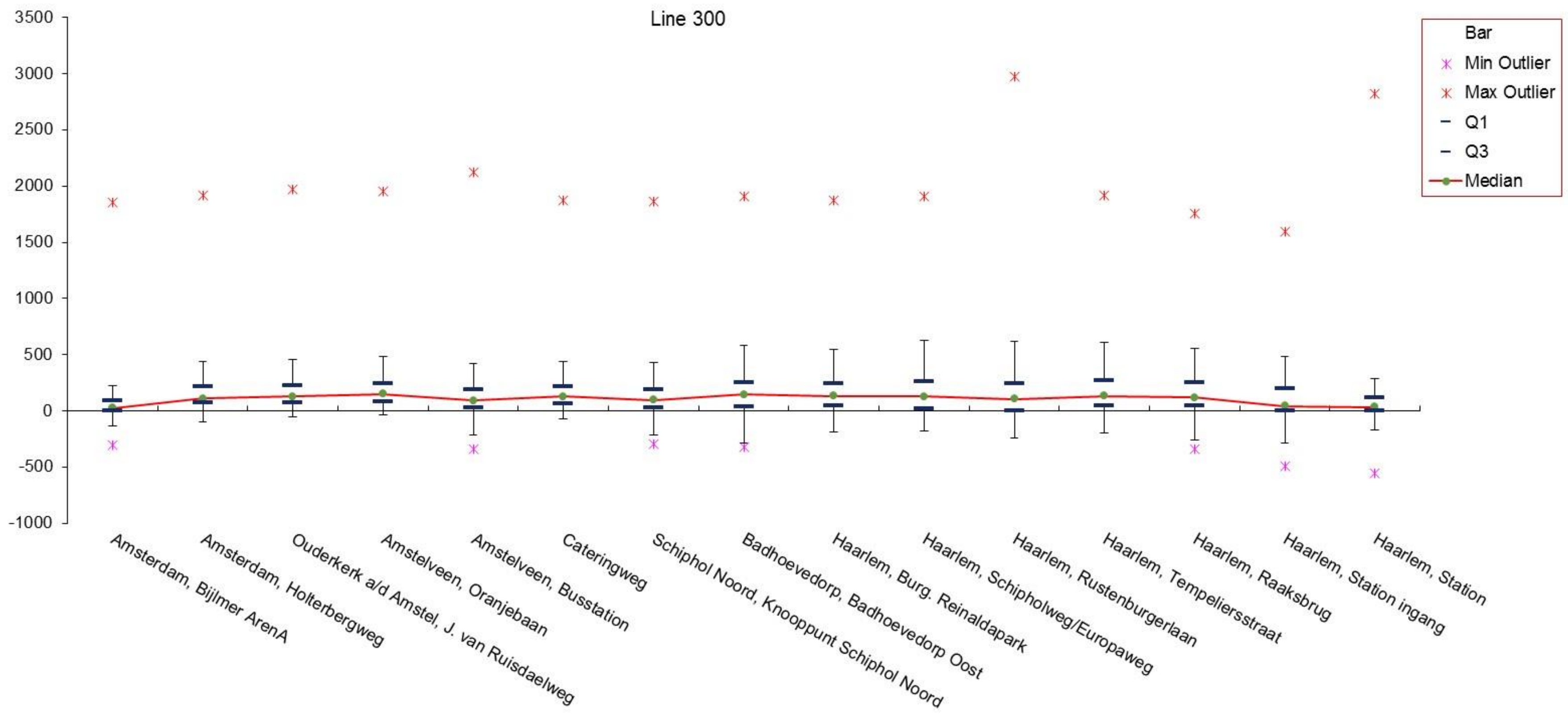
Parameter	Value
$n_{l,j}$ (#)	14
$n_{l,i}$ (#)	4920
p_l (s)	126

Table 172: Average deviation of too late/early departures on line 356

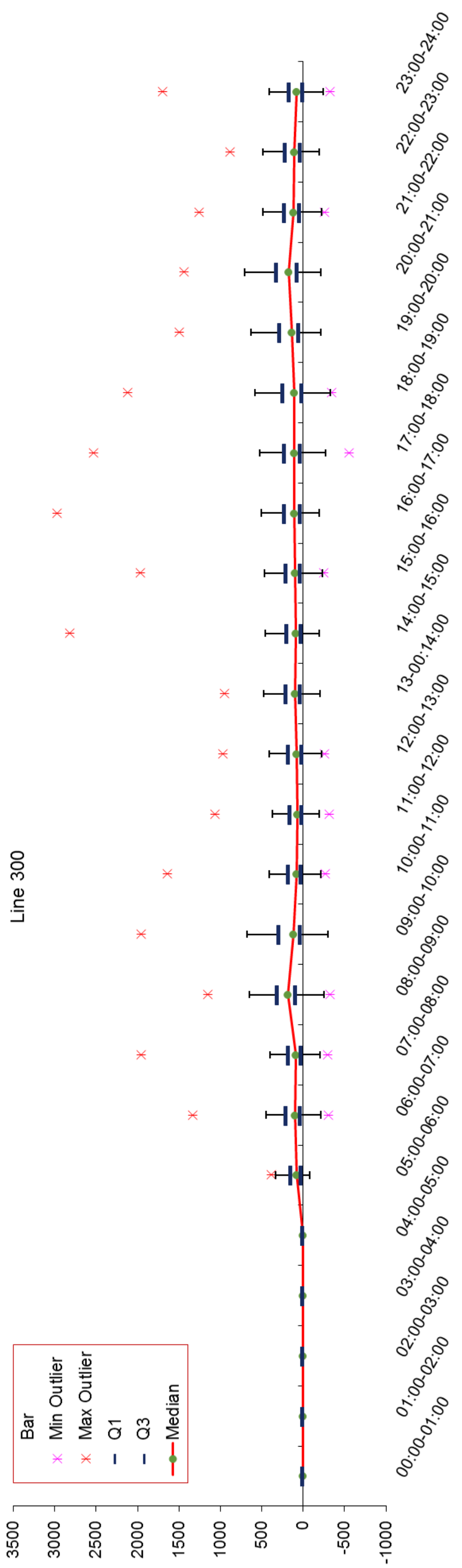
Parameter	Value
$n_{l,j}$ (#)	114
$n_{l,i}$ (#)	4920
p_l (s)	46

Table 173: Percentage of on-time departures of Line 356

# late/early	26415
Total	63896
% on time	59%



Line 300
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
Amsterdam, Bijlmer ArenA
Amsterdam, Holterbergweg
Ouderkerk a/d Amstel, J. van Ruisdaelweg
Amstelveen, Oranjebaan
Amstelveen, Busstation
Cateringweg
Schiphol Noord, Knooppunt Schiphol Noord
Badhoevedorp, Badhoevedorp Oost
Haarlem, Burg. Reinaldapark
Haarlem, Schipholweg/Europaweg
Haarlem, Rustenburgerlaan
Haarlem, Tempeliersstraat
Haarlem, Raaksbrug
Haarlem, Station ingang
Haarlem, Station


Line 300
Bar
Min Outlier
Max Outlier
Q1
Q3
Median
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
00:00-01:00
01:00-02:00
02:00-03:00
03:00-04:00
04:00-05:00
05:00-06:00
06:00-07:00
07:00-08:00
08:00-09:00
09:00-10:00
10:00-11:00
11:00-12:00
12:00-13:00
13:00-14:00
14:00-15:00
15:00-16:00
16:00-17:00
17:00-18:00
18:00-19:00
19:00-20:00
20:00-21:00
21:00-22:00
22:00-23:00
23:00-24:00

H. Regression Analyses

Three different relationships between characteristics of the different systems have been assessed. These include:

- The stop density of the bus service;
- The speed of the bus service;
- The frequency of the bus service;

Each relation has been assessed four times, for bike access, bike egress, walking access and walking egress.

Stop Density and Catchment area

Bike Access

Table 174: Stop and Catchment Bike Access

	Data	
	Input X	Input Y
	Stops	Catch
line 145	1,91	1,992
line 146	1,44	1,274
line 162	1,55	0
line 172	1,87	3,217
line 187	1,17	2,58
line 300	0,62	1,957
line 310	0,66	1,008
line 340	1,01	1,795
line 346	0,46	1,655
line 356	0,42	2,5958

SAMENVATTING UITVOER								
Gegevens voor de regressie								
Meervoudige correlatiecoëfficiënt R	0,029498709							
R-kwadraat	0,000870174							
Aangepaste kleinste kwadraat	-0,124021054							
Standaardfout	0,966249898							
Waarnemingen	10							
Variantie-analyse								
	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*			
Regressie	1	0,006505085	0,006505085	0,006967454	0,935527696			
Storing	8	7,469110925	0,933638866					
Totaal	9	7,47561601						
	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	1,754536334	0,703006049	2,495762785	0,037186761	0,133401479	3,37567119	0,133401479	3,37567119
Variabele X 1	0,047568109	0,569874002	0,083471274	0,935527696	-1,266563697	1,361699915	-1,266563697	1,361699915

Figure 80: Stop and Catchment Bike Access

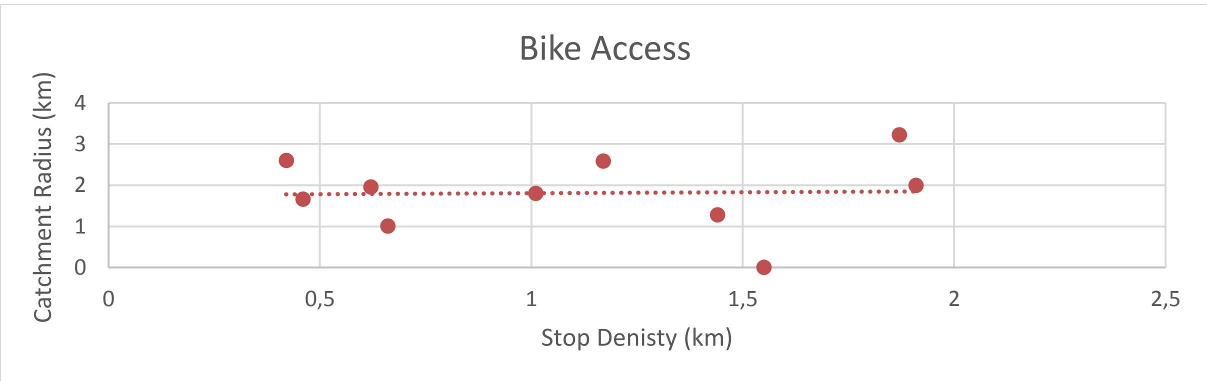


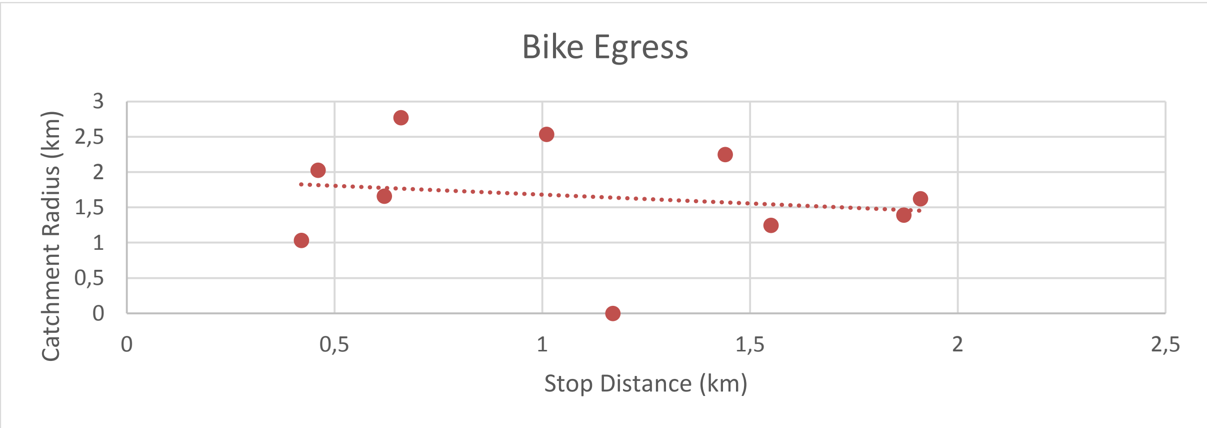
Figure 81: Visualisation Stop and Catchment Bike Access

Bike Egress

Table 175: Stop and Catchment Bike Egress

	Data	
	Input X	Input Y
	Stops	Catch
line 145	1,91	1,624
line 146	1,44	2,2507
line 162	1,55	1,245
line 172	1,87	1,39
line 187	1,17	0
line 300	0,62	1,6587
line 310	0,66	2,772
line 340	1,01	2,5356
line 346	0,46	2,025
line 356	0,42	1,0331

SAMENVATTING UITVOER								
Gegevens voor de regressie								
Meervoudige correlatiecoëfficiënt R	0,109223109							
R-kwadraat	0,011929688							
Aangepaste kleinste kwadraat	-0,111579102							
Standaardfout	0,973720998							
Waarnemingen	10							
Variantie-analyse								
	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*			
Regressie	1	0,091579923	0,091579923	0,096589786	0,763904413			
Storing	8	7,585060652	0,948132581					
Totaal	9	7,676640575						
	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	1,266520267	0,708441732	1,787755026	0,11162149	-0,367149296	2,90018983	-0,367149296	2,90018983
Variabele X 1	0,178479985	0,574280301	0,310788973	0,763904413	-1,145812764	1,502772734	-1,145812764	1,502772734



Walking access

Table 176: Stop and Catchment Walking Access

	Data	
	Input X	Input Y
	Stops	Catch
line 145	1,91	0,76
line 146	1,44	0,665
line 162	1,55	0,586
line 172	1,87	0,683
line 187	1,17	0,425
line 300	0,62	1,033
line 310	0,66	0,891
line 340	1,01	0,71
line 346	0,46	0,83
line 356	0,42	0,644

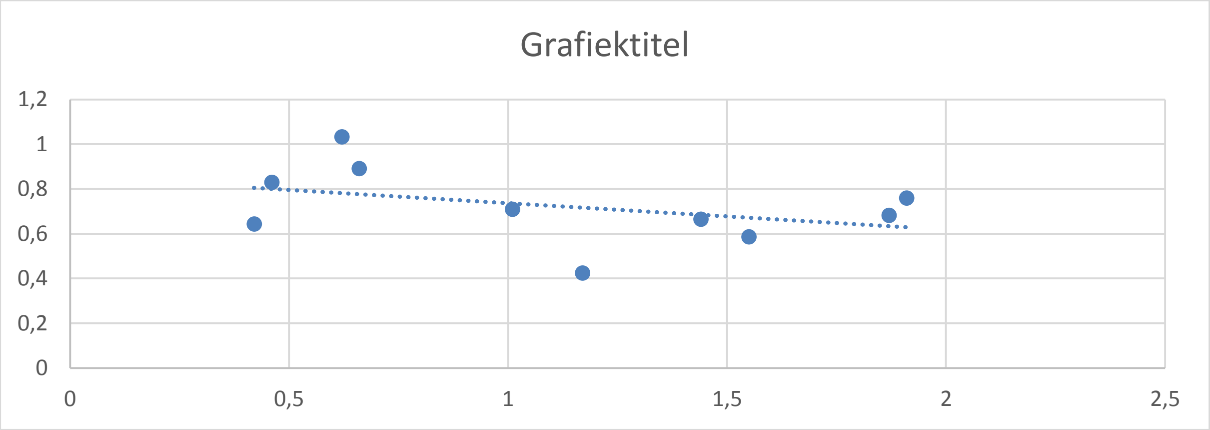
SAMENVATTING UITVOER

Gegevens voor de regressie	
Meervoudige correlatiecoëfficiënt R	0,395481253
R-kwadraat	0,156405421
Aangepaste kleinste kwadraat	0,050956099
Standaardfout	0,164329902
Waarnemingen	10

Variantie-analyse

	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*
Regressie	1	0,040053567	0,040053567	1,483228318	0,257968522
Storing	8	0,216034533	0,027004317		
Totaal	9	0,2560881			

	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	0,853836637	0,11956008	7,141486009	9,79077E-05	0,578130599	1,129542676	0,578130599	1,129542676
Variabele X 1	-0,118034777	0,096918343	-1,217878614	0,257968522	-0,341528876	0,105459322	-0,341528876	0,105459322



Walking egress

Table 177: Stop and Catchment Walking Egress

	Data	
	Input X	Input Y
	Stops	Catch
line 145	1,91	0,6524
line 146	1,44	0,5789
line 162	1,55	0,523
line 172	1,87	0,6069
line 187	1,17	0,393
line 300	0,62	0,706
line 310	0,66	0,661
line 340	1,01	0,526
line 346	0,46	0,786
line 356	0,42	0,718

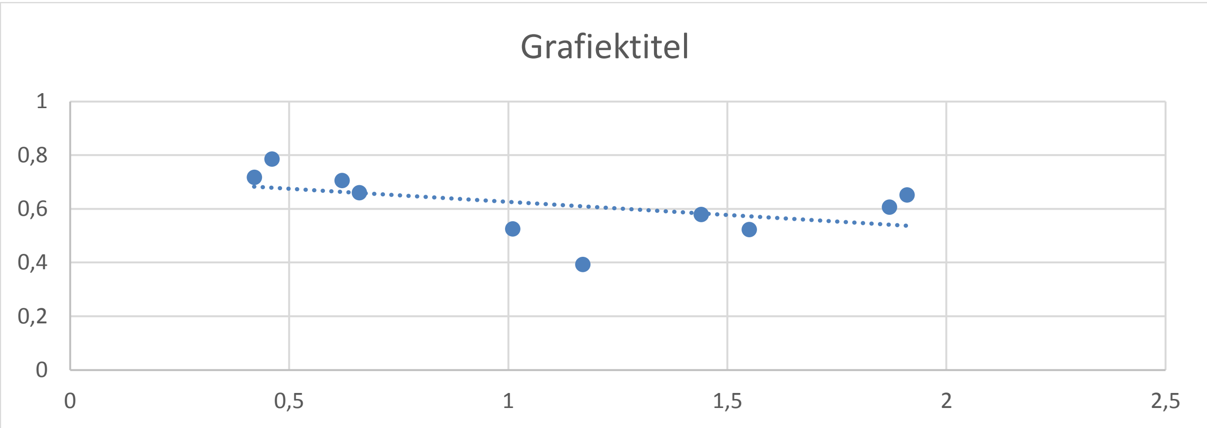
SAMENVATTING UITVOER

Gegevens voor de regressie	
Meervoudige correlatiecoëfficiënt R	0,480308631
R-kwadraat	0,230696381
Aangepaste kleinste kwadraat	0,134533429
Standaardfout	0,106831407
Waarnemingen	10

Variantie-analyse

	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*
Regressie	1	0,027379839	0,027379839	2,399015164	0,160004006
Storing	8	0,091303597	0,01141295		
Totaal	9	0,118683436			

	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	0,723542368	0,077726399	9,308836803	1,44508E-05	0,54430497	0,902779767	0,54430497	0,902779767
Variabele X 1	-0,09758989	0,063006932	-1,548875451	0,160004006	-0,242884136	0,047704356	-0,242884136	0,047704356



Service Speed and Catchment area

Bike Access

Table 178: Speed and Catchment Bike Access

	Data	
	Input X	Input Y
	Speed	Catch
line 145	27	1,992
line 146	35	1,274
line 162	26	0
line 172	22	3,217
line 187	31	2,58
line 300	37	1,957
line 310	35	1,008
line 340	27	1,795
line 346	40	1,655
line 356	38	2,5958

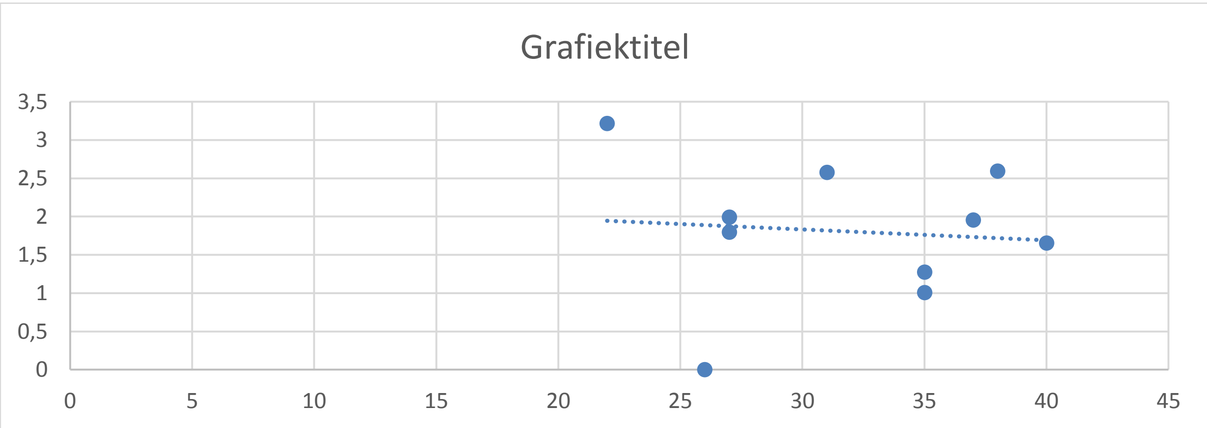
SAMENVATTING UITVOER

Gegevens voor de regressie	
Meervoudige correlatiecoëfficiënt R	0,093157072
R-kwadraat	0,00867824
Aangepaste kleinste kwadraat	-0,11523698
Standaardfout	0,962466936
Waarnemingen	10

Variantie-analyse

	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*
Regressie	1	0,064875191	0,064875191	0,07003369	0,797978176
Storing	8	7,410740819	0,926342602		
Totaal	9	7,47561601			

	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	2,25352623	1,713105312	1,315462753	0,224802363	-1,696901704	6,203954163	-1,696901704	6,203954163
Variabele X 1	-0,014029614	0,053014201	-0,264638792	0,797978176	-0,13628058	0,108221352	-0,13628058	0,108221352



Bike Egress

Table 179: Speed and Catchment Bike Egress

	Data	
	Input X	Input Y
	Speed	Catch
line 145	27	1,624
line 146	35	2,2507
line 162	26	1,245
line 172	22	1,39
line 187	31	0
line 300	37	1,6587
line 310	35	2,772
line 340	27	2,5356
line 346	40	2,025
line 356	38	1,0331

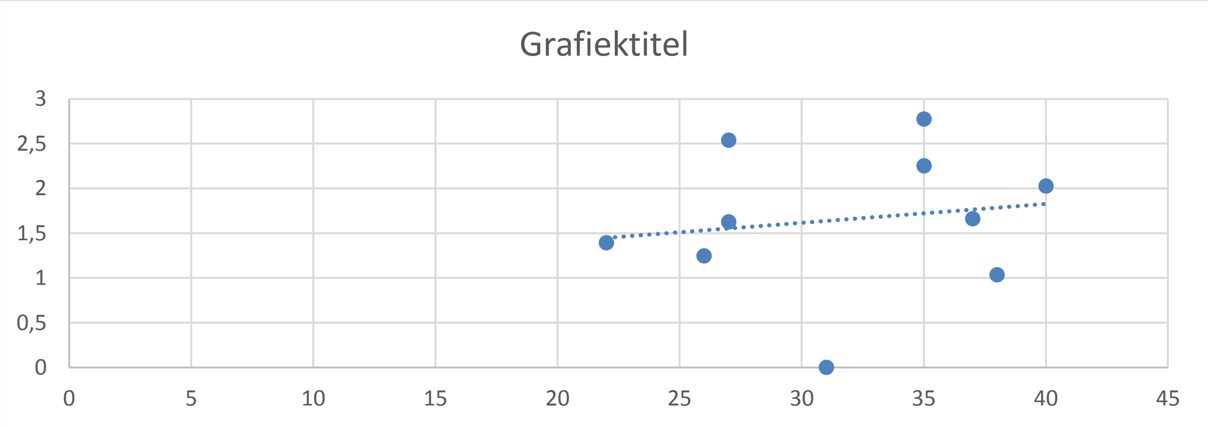
SAMENVATTING UITVOER

Gegevens voor de regressie	
Meervoudige correlatiecoëfficiënt R	0,156715945
R-kwadraat	0,024559887
Aangepaste kleinste kwadraat	-0,097370127
Standaardfout	0,846724064
Waarnemingen	10

Variantie-analyse

	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*
Regressie	1	0,144410759	0,144410759	0,201426101	0,665480052
Storing	8	5,735533123	0,71694164		
Totaal	9	5,879943882			

	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	0,987780907	1,507093322	0,655421196	0,530588536	-2,487582526	4,46314434	-2,487582526	4,46314434
Variabele X 1	0,020931781	0,0466389	0,448805193	0,665480052	-0,086617716	0,128481277	-0,086617716	0,128481277



Walking access

Table 180: Speed and Catchment Walking Access

	Data	
	Input X	Input Y
	Speed	Catch
line 145	27	0,76
line 146	35	0,665
line 162	26	0,586
line 172	22	0,683
line 187	31	0,425
line 300	37	1,033
line 310	35	0,891
line 340	27	0,71
line 346	40	0,83
line 356	38	0,644

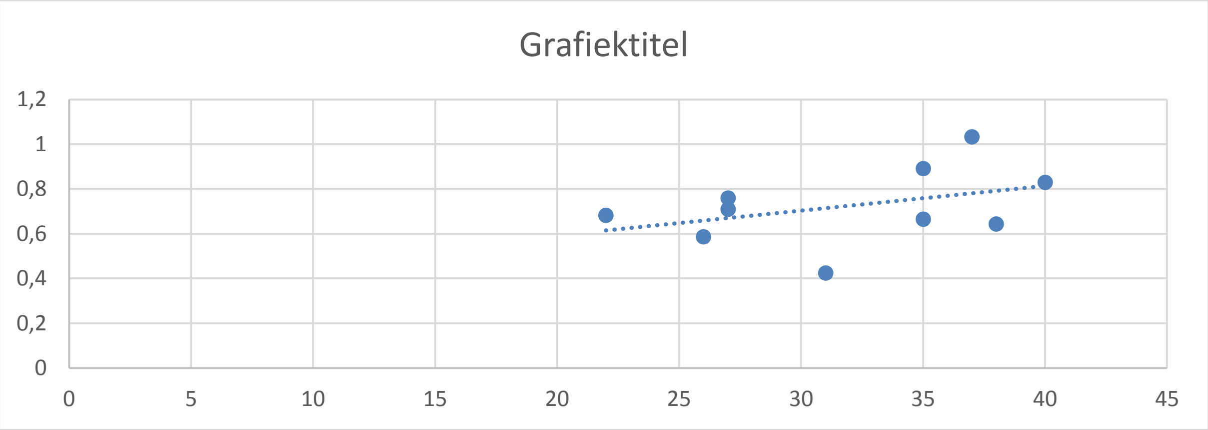
SAMENVATTING UITVOER

Gegevens voor de regressie	
Meervoudige correlatiecoëfficiënt R	0,398528034
R-kwadraat	0,158824594
Aangepaste kleinste kwadraat	0,053677668
Standaardfout	0,164094108
Waarnemingen	10

Variantie-analyse

	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*
Regressie	1	0,040673088	0,040673088	1,510501545	0,253984475
Storing	8	0,215415012	0,026926876		
Totaal	9	0,2560881			

	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	0,369445995	0,292072879	1,264910307	0,24150423	-0,304075272	1,042967262	-0,304075272	1,042967262
Variabele X 1	0,011108617	0,009038563	1,229024632	0,253984475	-0,009734347	0,03195158	-0,009734347	0,03195158



Walking egress

Table 181: Speed and Catchment Walking Egress

	Data	
	Input X	Input Y
	Speed	Catch
line 145	27	0,6524
line 146	35	0,5789
line 162	26	0,523
line 172	22	0,6069
line 187	31	0,393
line 300	37	0,706
line 310	35	0,661
line 340	27	0,526
line 346	40	0,786
line 356	38	0,718

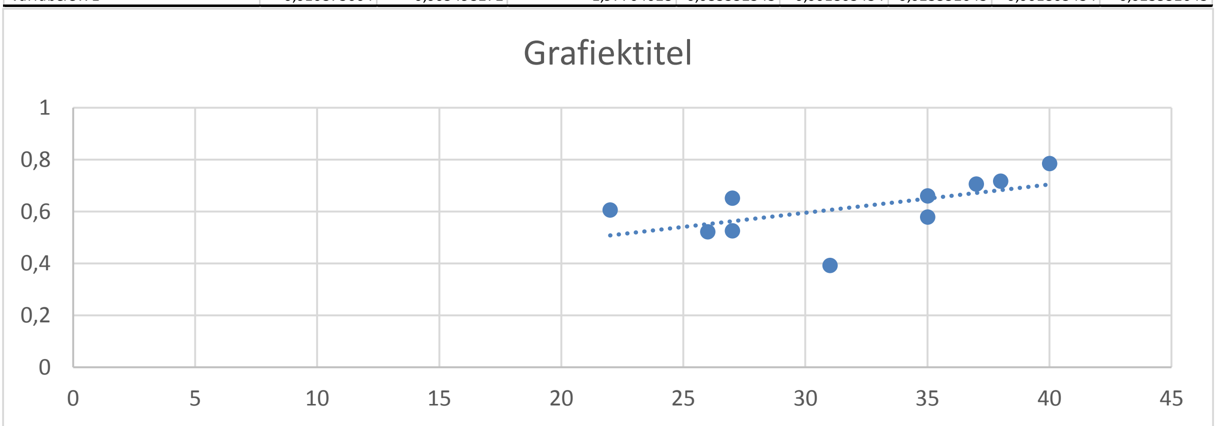
SAMENVATTING UITVOER

Gegevens voor de regressie	
Meervoudige correlatiecoëfficiënt R	0,573023025
R-kwadraat	0,328355388
Aangepaste kleinste kwadraat	0,244399811
Standaardfout	0,09982052
Waarnemingen	10

Variantie-analyse

	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*
Regressie	1	0,038970346	0,038970346	3,911061078	0,083352543
Storing	8	0,07971309	0,009964136		
Totaal	9	0,118683436			

	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	0,269339381	0,177671624	1,515939206	0,016800423	-0,140372119	0,679050881	-0,140372119	0,679050881
Variabele X 1	0,010873604	0,005498272	1,97764028	0,083352543	-0,001805434	0,023552643	-0,001805434	0,023552643



Service Frequency and Catchment Area

Bike Access

Table 182: Frequency and Catchment Bike Access

	Data	
	Input X	Input Y
	Frequency	Catch
line 145	4	1,992
line 146	4	1,274
line 162	1	0
line 172	6	3,217
line 187	4	2,58
line 300	10	1,957
line 310	10	1,008
line 340	8	1,795
line 346	11	1,655
line 356	8	2,5958

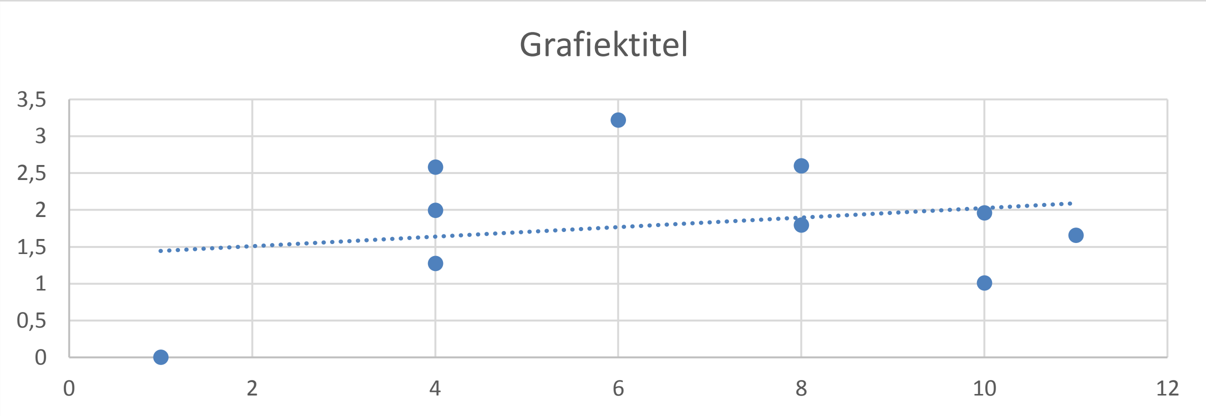
SAMENVATTING UITVOER

Gegevens voor de regressie	
Meervoudige correlatiecoëfficiënt R	0,235247876
R-kwadraat	0,055341563
Aangepaste kleinste kwadraat	-0,062740742
Standaardfout	0,93954136
Waarnemingen	10

Variantie-analyse

	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*
Regressie	1	0,413712275	0,413712275	0,468669402	0,512941118
Storing	8	7,061903736	0,882737967		
Totaal	9	7,47561601			

	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	1,379431982	0,692132085	1,993018401	0,08139167	-0,216627469	2,975491433	-0,216627469	2,975491433
Variabele X 1	0,064841291	0,094714911	0,684594334	0,512941118	-0,153571684	0,283254267	-0,153571684	0,283254267



Bike Egress

Table 183: Frequency and Catchment Bike Egress

	Data	
	Input X	Input Y
	Frequency	Catch
line 145	4	1,624
line 146	4	2,2507
line 162	1	1,245
line 172	6	1,39
line 187	4	0
line 300	10	1,6587
line 310	10	2,772
line 340	8	2,5356
line 346	11	2,025
line 356	8	1,0331

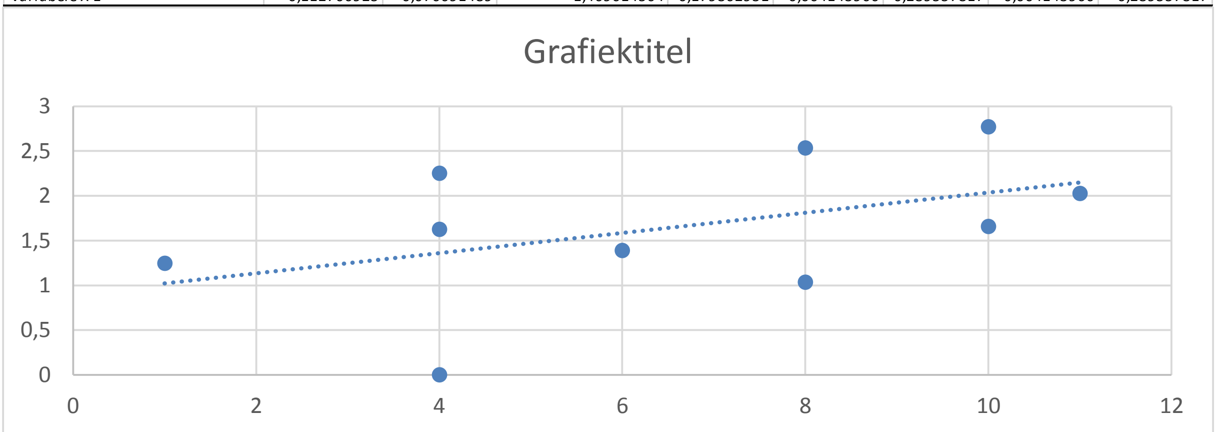
SAMENVATTING UITVOER

Gegevens voor de regressie	
Meervoudige correlatiecoëfficiënt R	0,461064368
R-kwadraat	0,212580351
Aangepaste kleinste kwadraat	0,114152895
Standaardfout	0,760754835
Waarnemingen	10

Variantie-analyse

	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*
Regressie	1	1,249960534	1,249960534	2,15976679	0,179862931
Storing	8	4,629983348	0,578747918		
Totaal	9	5,879943882			

	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	0,909545825	0,560425387	1,622956144	0,14325512	-0,382797435	2,201889085	-0,382797435	2,201889085
Variabele X 1	0,112706925	0,076691489	1,469614504	0,179862931	-0,064143966	0,289557817	-0,064143966	0,289557817



Walking Access

Table 184: Frequency and Catchment Walking Access

	Data	
	Input X	Input Y
	Frequency	Catch
line 145	4	0,76
line 146	4	0,665
line 162	1	0,586
line 172	6	0,683
line 187	4	0,425
line 300	10	1,033
line 310	10	0,891
line 340	8	0,71
line 346	11	0,83
line 356	8	0,644

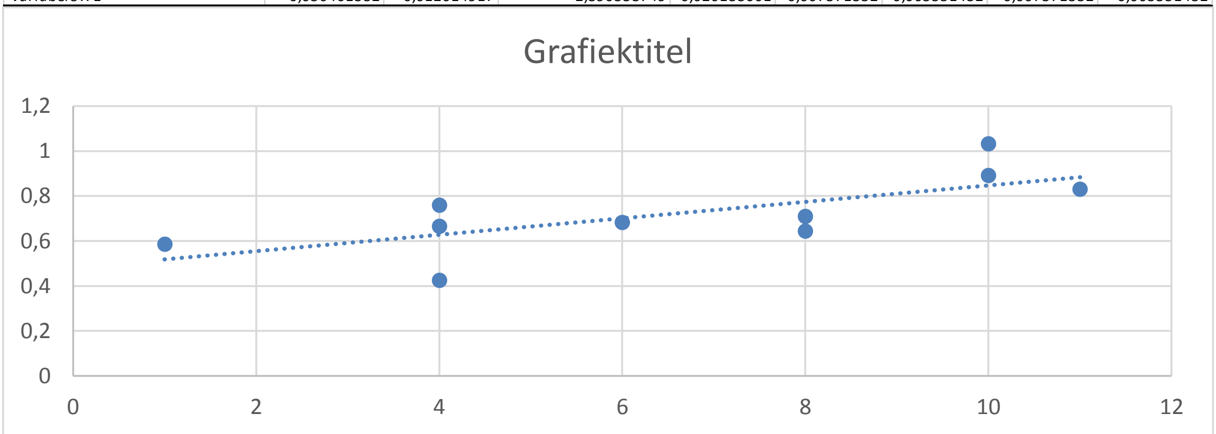
SAMENVATTING UITVOER

Gegevens voor de regressie	
Meervoudige correlatiecoëfficiënt R	0,714720069
R-kwadraat	0,510824778
Aangepaste kleinste kwadraat	0,449677875
Standaardfout	0,125135903
Waarnemingen	10

Variantie-analyse

	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*
Regressie	1	0,130816147	0,130816147	8,354058086	0,020188661
Storing	8	0,125271953	0,015658994		
Totaal	9	0,2560881			

	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	0,482054878	0,092183886	5,229274883	0,000793574	0,269478456	0,6946313	0,269478456	0,6946313
Variabele X 1	0,036461382	0,012614917	2,890338749	0,020188661	0,007371332	0,065551432	0,007371332	0,065551432

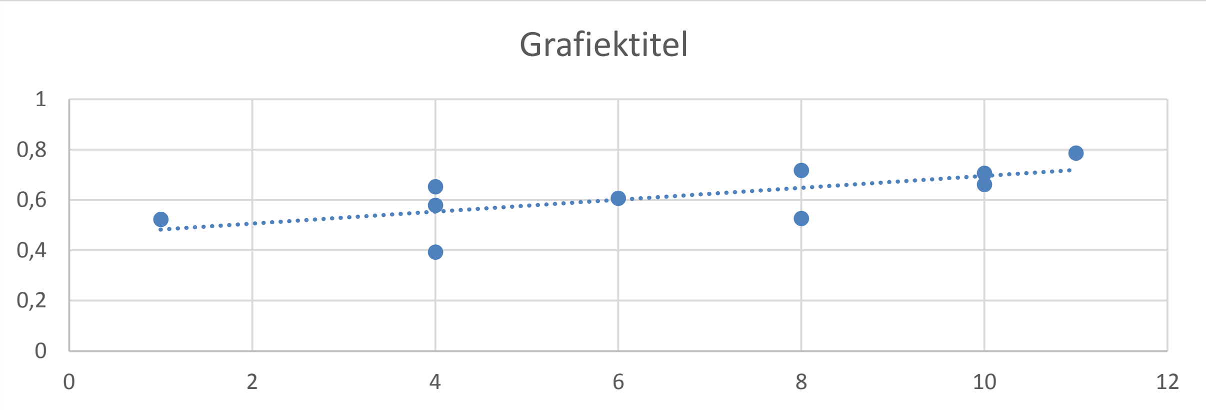


Walking Egress

Table 185: Frequency and Catchment Walking Egress

	Data	
	Input X	Input Y
	Frequency	Catch
line 145	4	0,6524
line 146	4	0,5789
line 162	1	0,523
line 172	6	0,6069
line 187	4	0,393
line 300	10	0,706
line 310	10	0,661
line 340	8	0,526
line 346	11	0,786
line 356	8	0,718

SAMENVATTING UITVOER								
Gegevens voor de regressie								
Meervoudige correlatiecoëfficiënt R	0,682301526							
R-kwadraat	0,465535373							
Aangepaste kleinste kwadraat	0,398727294							
Standaardfout	0,089045002							
Waarnemingen	10							
Variantie-analyse								
	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*			
Regressie	1	0,055251338	0,055251338	6,968249709	0,029725129			
Storing	8	0,063432098	0,007929012					
Totaal	9	0,118683436						
	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	0,458726829	0,065596796	6,993128623	0,000113414	0,307460347	0,609993311	0,307460347	0,609993311
Variabele X 1	0,023695935	0,008976603	2,639744251	0,029725129	0,002995852	0,044396018	0,002995852	0,044396018



Frequency and Speed

Waking Access

Table 186: Frequency and Speed Walking Access

	Data		
	Input X1	Input X2	Input Y
	Speed	Frequency	Catch
line 145	27	4	0,76
line 146	35	4	0,665
line 162	26	1	0,586
line 172	22	6	0,683
line 187	31	4	0,425
line 300	37	10	1,033
line 310	35	10	0,891
line 340	27	8	0,71
line 346	40	11	0,83
line 356	38	8	0,644

SAMENVATTING UITVOER								
Gegevens voor de regressie								
Meervoudige correlatiecoëfficiënt R	0,716787087							
R-kwadraat	0,513783727							
Aangepaste kleinste kwadraat	0,374864792							
Standaardfout	0,133370698							
Waarnemingen	10							
Variantie-analyse								
	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*			
Regressie	2	0,131573899	0,065786949	3,698442745	0,080149942			
Storing	7	0,124514201	0,017787743					
Totaal	9	0,2560881						
	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	0,528975562	0,24765522	2,13593544	0,070053508	-0,056635978	1,114587102	-0,056635978	1,114587102
Variabele X 1	-0,001927603	0,009339306	-0,206396851	0,842355812	-0,024011552	0,020156345	-0,024011552	0,020156345
Variabele X 2	0,038639731	0,017092699	2,260598593	0,058279909	-0,001778079	0,07905754	-0,001778079	0,07905754

Walking Egress

Table 187: Frequency and Speed Walking Egress

		Data	
	Input X1	X2	Input Y
	Speed	ncy	Catch
line 145	27	4	0,6524
line 146	35	4	0,5789
line 162	26	1	0,523
line 172	22	6	0,6069
line 187	31	4	0,393
line 300	37	10	0,706
line 310	35	10	0,661
line 340	27	8	0,526
line 346	40	11	0,786
line 356	38	8	0,718

SAMENVATTING UITVOER

Gegevens voor de regressie	
Meervoudige correlatiecoëfficiënt R	0,709042197
R-kwadraat	0,502740837
Aangepaste kleinste kwadraat	0,360666791
Standaardfout	0,091820031
Waarnemingen	10

Variantie-analyse

	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*
Regressie	2	0,05966701	0,029833505	3,538583221	0,086704129
Storing	7	0,059016426	0,008430918		
Totaal	9	0,118683436			

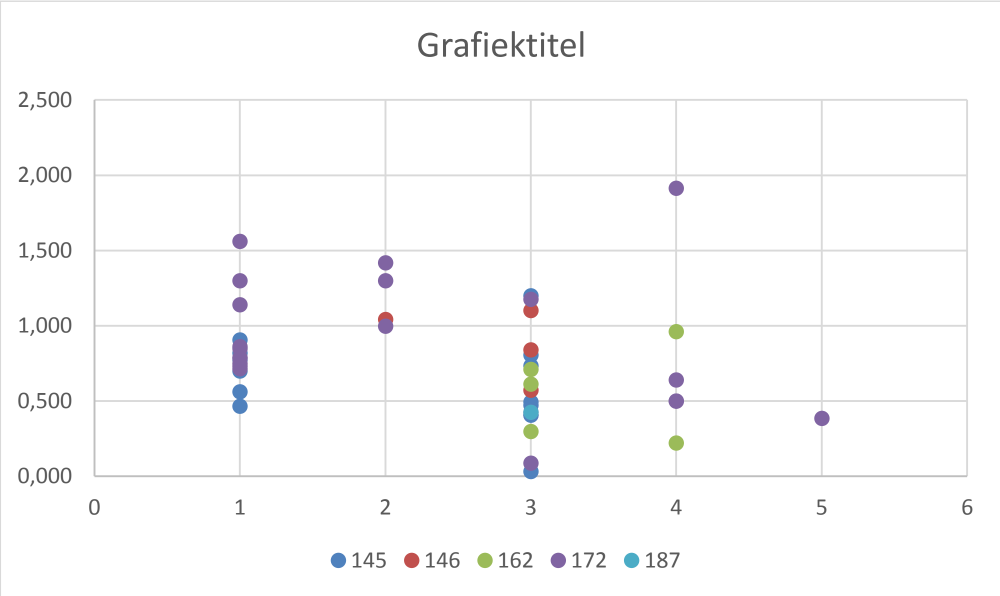
	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	0,345460907	0,170500044	2,026163154	0,082377832	-0,057707632	0,748629447	-0,057707632	0,748629447
Variabele X 1	0,004653209	0,006429713	0,723704024	0,492717274	-0,010550646	0,019857065	-0,010550646	0,019857065
Variabele X 2	0,01843743	0,011767593	1,56679705	0,161145788	-0,009388506	0,046263366	-0,009388506	0,046263366

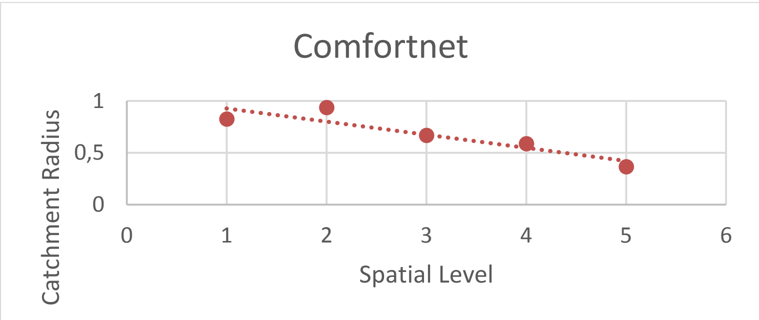
I. Stop Based Comparison

Spatial Analysis

Line		Spatial	Catchment Radius (km)
145	Amsterdam - Busstation Elandsgracht	1	0,766
145	Amsterdam - Leidseplein	1	0,660
145	Amsterdam - Rijksmuseum	1	1,043
145	Amsterdam - Museumplein	1	0,425
145	Amsterdam - Valeriusplein	1	0,773
145	Amsterdam - Hoofddorpplein	1	0,782
145	Amsterdam - Ottho Heldringstraat	1	1,226
145	Amsterdam - Aletta Jacobslaan	1	0,698
145	Amsterdam - Henk Sneevlietweg	1	0,694
145	Amsterdam - Armstrongstraat	1	0,418
145	Amsterdam - Langsom	3	1,390
145	Badhoevedorp - Rijstvogelstraat	3	0,493
145	Badhoevedorp - Spechtstraat	3	0,409
145	Badhoevedorp - Havikstraat	3	0,691
145	Badhoevedorp - Lorentzplein	3	0,739
145	Badhoevedorp - De Meerwende	3	0,820
145	Hoofddorp - Wijkermeerstraat	3	1,223
145	Hoofddorp - Beemsterstraat	3	0,734
145	Hoofddorp - Marktplein	3	0,489
145	Hoofddorp - Hoofddorp Centrum	3	0,685
145	Hoofddorp - Nieuweweg	3	0,690
145	Hoofddorp - Station	3	0,640
146	Amsterdam - Bijlmer Arena	3	0,853
146	Amstelveen - Ziekenhuis Hoofdingang	2	0,894
146	Amstelveen - Grote Beer	2	0,552
146	Uithoorn - Willem Klooslaan	3	0,552
146	Uithoorn - Heijermanslaan	3	0,530
146	Uithoorn - Romeflat	3	0,619
146	Uithoorn - Busstation	3	0,625
162	Lisse - Hyacinthenstraat	3	0,221
162	Lisse - Narcissenstraat	4	0,666
162	Nieuw-Vennep - Laan van Berlioz	2	0,560
162	Nieuw-Vennep - Getsewoud Centrum	3	0,436
162	Nieuw-Vennep - Haverstraat	4	0,703
162	Hoofddorp - Hoofddorp Centrum	3	0,410
162	Hoofddorp - Van den Berghlaan	3	0,688
162	Hoofddorp - Station	3	0,896
162	Nieuw-Vennep - Oosterdreef	5	0,364
172	Aalsmeer, Zwarteweg	4	0,537
172	Aalsmeer, Gloxiniastraat	4	0,429
172	Aalsmeer, Hortensiaplein	4	0,793
172	Aalsmeer, Gloxiniastraat	4	0,429
172	Aalsmeer, Zwarteweg	4	0,537
172	Amstelveen, Westwijkplein	3	0,410
172	Amstelveen, Bovenkerkerweg	2	1,687
172	Amstelveen, Handweg	2	1,075
172	Amstelveen, Busstation	2	0,836
172	Amstelveen, Dijkgravenlaan	1	0,563
172	Amstelveen, Graaf Florislaan	1	0,837
172	Amsterdam, Van Nijenrodeweg	1	2,434
172	Amsterdam, VU Medisch Centrum	1	0,644
172	Amsterdam, Amstelveenseweg	1	1,075
172	Amsterdam, IJsbaanpad	1	0,756
172	Amsterdam, Valeriusplein	1	0,690
172	Amsterdam, Emmastraat	1	0,648
172	Amsterdam, Museumplein	1	0,306
172	Amsterdam, Leidseplein	1	1,715
172	Amsterdam, Elandsgracht	1	0,511
172	Amsterdam, Marnixstraat	1	0,570
172	Amsterdam, Westermarkt	1	0,831
172	Amsterdam, Dam	1	0,494
172	Amsterdam, Centraal Station	1	1,014
187	Amstelveen - Busstation	3	0,775

Spatial Level	Catchment Radius (km)	Observations (#)
1	0,823	25
2	0,934	6
3	0,667	24
4	0,585	7
5	0,364	1

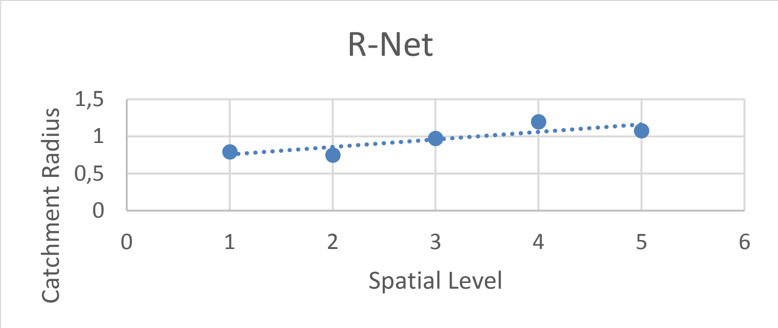


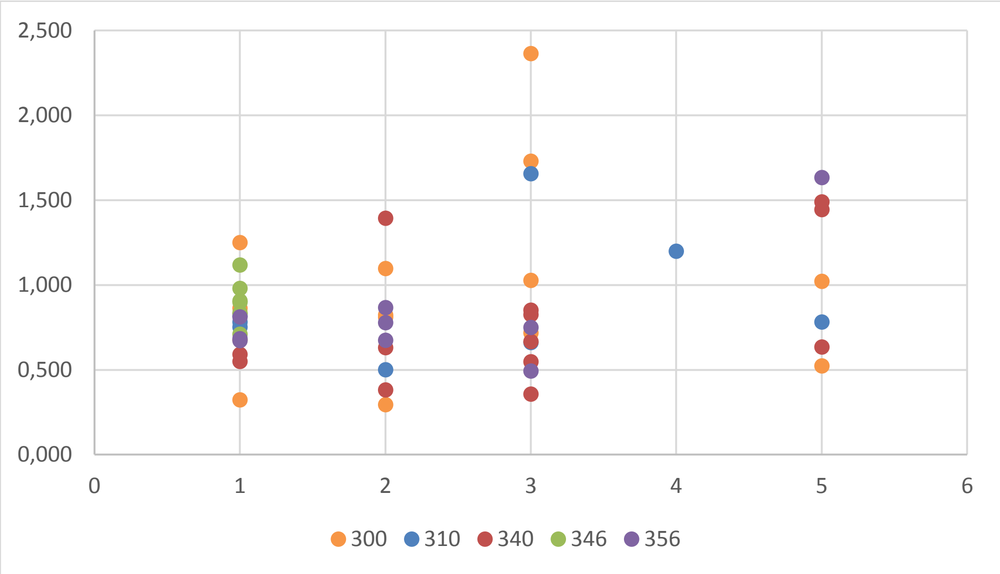


SAMENVATTING UITVOER								
Gegevens voor de regressie								
Meervoudige correlatiecoëfficiënt R	0,909880129							
R-kwadraat	0,82788185							
Aangepaste kleinste kwadraat	0,770509133							
Standaardfout	0,105409871							
Waarnemingen	5							
Variantie-analyse								
	Vrijheidsgraden	*Kwadratensom*	*Gemiddelde kwadraten*	*F*	*Significantie F*			
Regressie	1	0,160333955	0,160333955	14,4298875	0,032033554			
Storing	3	0,033333722	0,011111241					
Totaal	4	0,193667677						
	Coëfficiënten	*Standaardfout*	*T- statistische gegevens*	*P-waarde*	*Laagste 95%*	*Hoogste 95%*	*Laagste 95,0%*	*Hoogste 95,0%*
Snijpunt	1,054558924	0,110554805	9,538788699	0,002443822	0,702724193	1,406393655	0,702724193	1,406393655
Variabele X 1	-0,126623045	0,033333528	-3,798669175	0,032033554	-0,232705208	-0,020540882	-0,232705208	-0,020540882

Line		Spatial	Catchment Radius (km)
300	Amsterdam - Bijlmer ArenA	3	1,027
300	Amstelveen - Ouderkerkerlaan	2	1,097
300	Amstelveen - Busstation	2	0,824
300	Schiphol Centrum - Airport/Plaza	5	1,022
300	Schiphol Centrum - Handelskade	5	0,523
300	De Hoek - De Hoek	3	2,365
300	Hoofddorp - Graan voor Visch	3	0,718
300	Hoofddorp - Toolenburg	3	1,730
300	Hoofddorp - Bornholm	2	0,295
300	Hoofddorp - Spaarne Ziekenhuis	2	0,810
300	Haarlem - Schalkwijk Centrum	1	0,677
300	Haarlem - Europaweg	1	1,250
300	Haarlem - Centrum/Verwulft	1	0,324
300	Haarlem - Station	1	0,863
310	Nieuw-Vennep - Getsewoud Zuid	2	0,501
310	Nieuw-Vennep - Getsewoud Centrum	3	0,662
310	Hoofddorp - Graan voor Visch	4	1,199
310	Hoofddorp - Station	3	1,656
310	Schiphol Centrum - Airport/Plaza	5	0,783
310	Amsterdam - VU Medisch Centrum	1	0,819
310	Amsterdam - De Boelelaan/VU	1	0,752
310	Amsterdam - Station Zuid	1	0,782
340	Haarlem - Station	1	0,591
340	Haarlem - Tempeliersstraat	1	0,550
340	Heemstede - Wipperplein	2	0,631
340	Cruquius - Spieringweg	5	1,446
340	Hoofddorp - Spaarne Ziekenhuis	2	1,395
340	Hoofddorp - Houtwijkerveld	2	0,382
340	Hoofddorp - RK Kerk	3	0,357
340	Hoofddorp - Hoofddorp Centrum	3	0,549
340	Hoofddorp - Station	3	0,852
340	Aalsmeer - Dorpsstraat	5	1,491
340	Aalsmeer - van Cleeffkade	5	0,634
340	Uithoorn - Burg. Kootlaan	3	0,825
340	Uithoorn - Busstation	3	0,668
346	Amsterdam - Station Zuid	1	0,908
346	Amsterdam - De Boelelaan/VU	1	0,831
346	Amsterdam - VU Medisch Centrum	1	0,835
346	Amsterdam - Amstelveenseweg	1	1,118
346	Haarlem - Tempeliersstraat	1	0,899
346	Haarlem - Raaksbrug	1	0,981
346	Haarlem - Station	1	0,710
356	Amsterdam - Bijlmer ArenA	3	0,750
356	Amsterdam - Holterbergweg	3	0,493
356	Ouderkerk a/d Amstel - J. van Ruisdaelweg	5	1,634
356	Amstelveen - Oranjebaan	2	0,778
356	Amstelveen - Busstation	2	0,674
356	Haarlem - Schipholweg/Europaweg	2	0,868
356	Haarlem - Rustenburgerlaan	1	0,684
356	Haarlem - Tempeliersstraat	1	0,672
356	Haarlem - Raaksbrug	1	0,812

Spatial Level	Catchment Radius (km)	Observations (#)
1	0,792	19
2	0,751	11
3	0,973	13
4	1,199	1
5	1,076	7


R-Net
Catchment Radius
1,5
1
0,5
0
0
1
2
3
4
5
6
Spatial Level


2,500
2,000
1,500
1,000
0,500
0,000
0
1
2
3
4
5
6
300
310
340
346
356

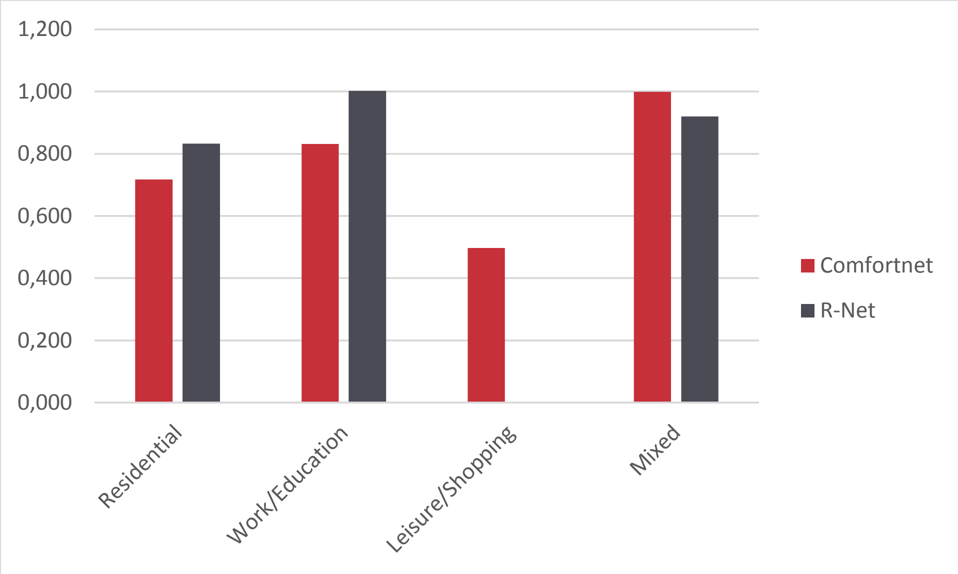
Activity Analysis

Line		Activity	Catchment Radius (km)
145	Amsterdam - Busstation Elandsgracht	Residential	0,766
145	Amsterdam - Leidseplein	Work/Education	0,660
145	Amsterdam - Rijksmuseum	Leisure/Shopping	1,043
145	Amsterdam - Museumplein	Leisure/Shopping	0,425
145	Amsterdam - Valeriusplein	Mixed	0,773
145	Amsterdam - Hoofddorpplein	Mixed	0,782
145	Amsterdam - Ottho Heldringstraat	Mixed	1,226
145	Amsterdam - Aletta Jacobslaan	Mixed	0,698
145	Amsterdam - Henk Sneevlietweg	Mixed	0,694
145	Amsterdam - Armstrongstraat	Mixed	0,418
145	Amsterdam - Langsom	Residential	1,390
145	Badhoevedorp - Rijstvogelstraat	Residential	0,493
145	Badhoevedorp - Spechtstraat	Residential	0,409
145	Badhoevedorp - Havikstraat	Residential	0,691
145	Badhoevedorp - Lorentzplein	Residential	0,739
145	Badhoevedorp - De Meerwende	Residential	0,820
145	Hoofddorp - Wijkermeerstraat	Residential	1,223
145	Hoofddorp - Beemsterstraat	Residential	0,734
145	Hoofddorp - Marktplein	Residential	0,489
145	Hoofddorp - Hoofddorp Centrum	Work/Education	0,685
145	Hoofddorp - Nieuweweg	Work/Education	0,690
145	Hoofddorp - Station	Work/Education	0,640
146	Amsterdam - Bijlmer Arena	Work/Education	0,853
146	Amstelveen - Ziekenhuis Hoofdingang	Residential	0,894
146	Amstelveen - Grote Beer	Work/Education	0,552
146	Uithoorn - Willem Klooslaan	Residential	0,552
146	Uithoorn - Heijermanslaan	Residential	0,530
146	Uithoorn - Romeflat	Residential	0,619
146	Uithoorn - Busstation	Residential	0,625
162	Lisse - Hyacinthenstraat	Residential	0,221
162	Lisse - Narcissenstraat	Residential	0,666
162	Nieuw-Vennep - Laan van Berlioz	Residential	0,560
162	Nieuw-Vennep - Getsewoud Centrum	Residential	0,436
162	Nieuw-Vennep - Haverstraat	Work/Education	0,703
162	Hoofddorp - Hoofddorp Centrum	Work/Education	0,410
162	Hoofddorp - Van den Berghlaan	Work/Education	0,688
162	Hoofddorp - Station	Work/Education	0,896
172	Aalsmeer - Zwarteweg	Residential	0,537
172	Aalsmeer - Gloxiniastraat	Mixed	0,429
172	Aalsmeer - Hortensiaplein	Mixed	0,793
172	Aalsmeer - Gloxiniastraat	Mixed	0,429
172	Aalsmeer - Zwarteweg	Mixed	0,537
172	Amstelveen - Westwijkplein	Residential	0,410
172	Amstelveen - Bovenkerkerweg	Residential	1,687
172	Amstelveen - Handweg	Residential	1,075
172	Amstelveen - Busstation	Residential	0,836
172	Amstelveen - Dijkgravenlaan	Residential	0,563
172	Amstelveen - Graaf Florislaan	Residential	0,837
172	Amsterdam - Van Nijenrodeweg	Residential	2,434
172	Amsterdam - VU Medisch Centrum	Work/Education	0,644
172	Amsterdam - Amstelveenseweg	Mixed	1,075
172	Amsterdam - IJsbaanpad	Mixed	0,756
172	Amsterdam - Valeriusplein	Mixed	0,690
172	Amsterdam - Emmastraat	Leisure/Shopping	0,648
172	Amsterdam - Museumplein	Leisure/Shopping	0,306
172	Amsterdam - Leidseplein	Work/Education	1,715
172	Amsterdam - Elandsgracht	Residential	0,511
172	Amsterdam - Marnixstraat	Residential	0,570
172	Amsterdam - Westermarkt	Residential	0,831
172	Amsterdam - Dam	Leisure/Shopping	0,494
172	Amsterdam - Centraal Station	Residential	1,014
187	Amstelveen - Busstation	Residential	0,775

Line		Spatial	Catchment Radius (km)
300	Amsterdam - Bijlmer ArenA	Work/Education	1,027
300	Amstelveen - Ouderkerkerlaan	Residential	1,097
300	Amstelveen - Busstation	Residential	0,824
300	Schiphol Centrum - Airport/Plaza	Work/Education	1,022
300	Schiphol Centrum - Handelskade	Work/Education	0,523
300	De Hoek - De Hoek	Work/Education	2,365
300	Hoofddorp - Graan voor Visch	Work/Education	0,718
300	Hoofddorp - Toolenburg	Residential	1,730
300	Hoofddorp - Bornholm	Residential	0,295
300	Hoofddorp - Spaarne Ziekenhuis	Mixed	0,810
300	Haarlem - Schalkwijk Centrum	Mixed	0,677
300	Haarlem - Europaweg	Mixed	1,250
300	Haarlem - Centrum/Verwulft	Mixed	0,324
300	Haarlem - Station	Mixed	0,863
310	Nieuw-Vennep - Getsewoud Zuid	Residential	0,501
310	Nieuw-Vennep - Getsewoud Centrum	Residential	0,662
310	Hoofddorp - Graan voor Visch	Work/Education	1,199
310	Hoofddorp - Station	Work/Education	1,656
310	Schiphol Centrum - Airport/Plaza	Work/Education	0,783
310	Amsterdam - VU Medisch Centrum	Work/Education	0,819
310	Amsterdam - De Boelelaan/VU	Residential	0,752
310	Amsterdam - Station Zuid	Residential	0,782
340	Cruquius - Spieringweg	Work/Education	1,446
340	Hoofddorp - Spaarne Ziekenhuis	Mixed	1,395
340	Hoofddorp - Houtwijkerveld	Residential	0,382
340	Hoofddorp - RK Kerk	Residential	0,357
340	Hoofddorp - Hoofddorp Centrum	Work/Education	0,549
340	Hoofddorp - Station	Work/Education	0,852
340	Aalsmeer - Dorpsstraat	Residential	1,491
340	Aalsmeer - van Cleeffkade	Residential	0,634
340	Uithoorn - Burg. Kootlaan	Residential	0,825
340	Uithoorn - Busstation	Residential	0,668
346	Amsterdam - Station Zuid	Residential	0,908
346	Amsterdam - De Boelelaan/VU	Residential	0,831
346	Amsterdam - VU Medisch Centrum	Work/Education	0,835
346	Amsterdam - Amstelveenseweg	Mixed	1,118
356	Amsterdam - Bijlmer ArenA	Work/Education	0,750
356	Amsterdam - Holterbergweg	Work/Education	0,493
356	Ouderkerk a/d Amstel - J. van Ruisdaelweg	Residential	1,634
356	Amstelveen - Oranjebaan	Residential	0,778
356	Amstelveen - Busstation	Residential	0,674

Activity	Catchment Radius (km)	Observations (#)
Residential	0,779	32
Work/Education	0,761	12
Leisure/Shopping	0,583	5
Mixed	0,715	13

Activity	Catchment Radius (km)	Observations (#)
Residential	0,833	19
Work/Education	1,002	15
Leisure/Shopping	-	0
Mixed	0,920	7



Stop Type Analysis

Access

Line	Stop	#access	% access	Catchment Radius (km)
145	Amsterdam - Henk Sneevlietweg	6	100%	0,858
145	Hoofddorp - Marktplein	6	100%	0,708
145	Hoofddorp - Hoofddorp Centrum	10	71%	0,693
146	Amstelveen - Ziekenhuis Hoofdingang	5	71%	1,042
172	Aalsmeer - Floraholland Hoofdingang	8	89%	1,915
300	Amstelveen - Ouderkerkerlaan	6	75%	1,206
310	Amsterdam - VU Medisch Centrum	10	91%	0,831
310	Amsterdam - De Boelelaan/VU	14	93%	0,891
310	Amsterdam - Station Zuid	6	100%	1,193
340	Hoofddorp - Station	12	71%	0,710
346	Amsterdam - Station Zuid	11	73%	1,047
346	Haarlem - Burg. Reinaldapark	7	100%	0,671
356	Amsterdam - Holterbergweg	6	86%	0,228
Total				0,923
CN				1,043
RN				0,847

Egress

Line	Stop	#egress	% egress	Radius
145	Amsterdam - Langsom	4	80%	0,818
145	Badhoevedorp - Lorentzplein	9	82%	0,406
146	Uithoorn - Busstation	7	70%	1,102
162	Lisse - Hyacinthenstraat	5	71%	0,297
162	Nieuw-Vennep - Station	4	80%	0,433
172	Amstelveen - Heemraadschapslaan	5	100%	0,621
172	Amsterdam - Nieuwezijds Kolk	7	100%	0,493
300	Hoofddorp - Toolenburg	4	80%	0,520
310	Nieuw-Vennep - Getsewoud Noord	11	85%	0,494
310	Hoofddorp - Toolenburg Oost	7	88%	0,442
310	Amsterdam - Amstelveenseweg	4	80%	1,159
340	Hoofddorp - Spaarne Ziekenhuis	6	75%	0,920
346	Amsterdam - Amstelveenseweg	8	80%	0,769
346	Haarlem - Schipholweg/Europaweg	5	71%	0,998
346	Haarlem - Raaksbrug	8	73%	0,421
356	Ouderkerk a/d Amstel - J. van Ruisdaelweg	4	80%	0,622
356	Badhoevedorp - Badhoevedorp Oost	6	75%	1,852
356	Haarlem - Burg. Reinaldapark	4	80%	0,860
Total				0,735
CN				0,596
RN				0,823

J. VENOM and Validation

Table 188: Line 172

Stop	DIFF	DIFF_%
Kudelstaart, Bilderdammerweg	0,005	0,6%
Kudelstaart, Calslager Bancken	0,003	0,8%
Kudelstaart, Gravin Aleidstraat	0,003	0,8%
Kudelstaart, Schweitzerstraat	0,003	0,6%
Kudelstaart, Einsteinstraat	0,000	0,1%
Kudelstaart, De Rietlanden	0,004	0,8%
Kudelstaart, Legmeerdijk	-0,001	-2,0%
Aalsmeer, Mozartlaan	0,003	1,0%
Aalsmeer, Beethovenlaan	0,004	1,0%
Aalsmeer, Zwarteweg	0,009	0,8%
Aalsmeer, Gloxiniastraat	-0,003	-1,6%
Aalsmeer, Hortensiaplein	0,010	0,7%
Aalsmeer, Gloxiniastraat	-0,003	-1,6%
Aalsmeer, Zwarteweg	0,009	0,8%
Aalsmeer, Mendelstraat	0,002	0,7%
Aalsmeer, P.F.von Sieboldlaan	0,001	0,2%
Aalsmeer, Floraholland West	-0,002	-7,0%
Aalsmeer, Floraholland Noord	0,005	0,9%
Aalsmeer, Floraholland Oost	0,004	1,0%
Aalsmeer, Floraholland Hoofdingang	-0,012	7,0%
Aalsmeer, Nieuw Oosteinde	-0,008	-3,1%
Amstelveen, Weldam	-0,010	8,4%
Amstelveen, Cannenburgh	0,012	1,0%
Amstelveen, Westwijkplein	-0,010	-2,2%
Amstelveen, Sacharovlaan	-0,013	-8,0%
Amstelveen, Bovenkerkerweg	-0,002	-0,3%
Amstelveen, Handweg	-0,009	-3,9%
Amstelveen, Lindenlaan	0,000	0,0%
Amstelveen, Icaruslaan	0,002	0,4%
Amstelveen, Keizer Karelplein	-0,004	-2,0%
Amstelveen, Busstation	-0,033	4,7%
Amstelveen, Heemraadschapslaan	-0,020	3,7%
Amstelveen, Kruiskerk	-0,011	-24,8%
Amstelveen, Dijkgravenlaan	-0,009	7,9%
Amstelveen, Graaf Florislaan	-0,013	17,1%
Amsterdam, Kalfjeslaan	-0,003	-0,6%
Amsterdam, Van Nijenrodeweg	-0,017	5,4%
Amsterdam, Koenenkade	0,003	0,5%
Amsterdam, VU Medisch Centrum	-0,038	3,0%
Amsterdam, Amstelveenseweg	-0,018	-30,6%
Amsterdam, IJsbaanpad	-0,024	3,1%
Amsterdam, Olympisch Stadion	-0,011	-73,7%
Amsterdam, Haarlemmermeerstation	-0,060	2,7%
Amsterdam, Valeriusplein	-0,034	2,9%
Amsterdam, Emmastraat	-0,011	16,4%
Amsterdam, Jacob Obrechtstraat	-0,011	6,8%
Amsterdam, Museumplein	-0,035	3,7%
Amsterdam, Rijksmuseum	-0,030	2,6%
Amsterdam, Leidseplein	-0,006	-1,0%
Amsterdam, Elandsgracht	-0,029	3,8%
Amsterdam, Marnixstraat	-0,023	4,5%
Amsterdam, Westermarkt	0,001	0,1%
Amsterdam, Dam	-0,001	-0,1%
Amsterdam, Nieuwezijds Kolk	-0,004	-2,2%
Amsterdam, Centraal Station	-0,006	-1,2%
MEAN		-0,9%

Table 189: Line 300

Stop	DIFF	DIFF_%
Amsterdam, Bijlmer ArenA	-0,098	2,3%
Amsterdam, Holterbergweg	-0,022	2,3%
Ouderkerk a/d Amstel	0,010	0,4%
Amstelveen, Langerhuize	-0,004	-0,5%
Amstelveen, Ouderkerkerlaan	-0,072	2,8%
Amstelveen, Busstation	-0,083	3,8%
Schiphol Noord, Cateringweg	0,032	1,0%
Schiphol Noord, Knooppunt Schiphol No	-0,012	-1,2%
Schiphol Noord, Elzenhof	0,021	1,0%
Schiphol Centrum, Airport/Plaza	-0,106	3,1%
Schiphol Centrum, Handelskade	-0,048	2,8%
De Hoek, De Hoek	0,006	0,4%
Hoofddorp, Beukenhorst	0,039	1,0%
Hoofddorp, Station	-0,028	-7,8%
Hoofddorp, Graan voor Visch	0,001	0,1%
Hoofddorp, Toolenburg	0,007	0,3%
Hoofddorp, Bornholm	0,024	0,8%
Hoofddorp, Overbos	0,004	0,2%
Hoofddorp, Spaarne Ziekenhuis	0,003	0,1%
Vijfhuizen, Vijfhuizen	0,026	0,8%
Hoofddorp, Expo Haarlemmermeer	0,029	1,0%
Haarlem, Schalkwijk Centrum	-0,003	-0,2%
Haarlem, Europaweg	-0,009	-0,8%
Haarlem, Centrum/Verwulft	0,036	0,9%
Haarlem, Station ingang	0,041	1,0%
Haarlem, Station	0,033	0,9%
MEAN		0,6%

K. Modelling of Alternatives

With Venom the alternatives as developed in chapter 7 are modelled. This appendix describes, per alternative, how the alternative has been developed and how they has been modelled in VENOM.

The only lines that are changed are line 172 and line 300 (in both directions). However, as VENOM uses base year 2010, services of lines might have changed.

Alternatives of Line 172

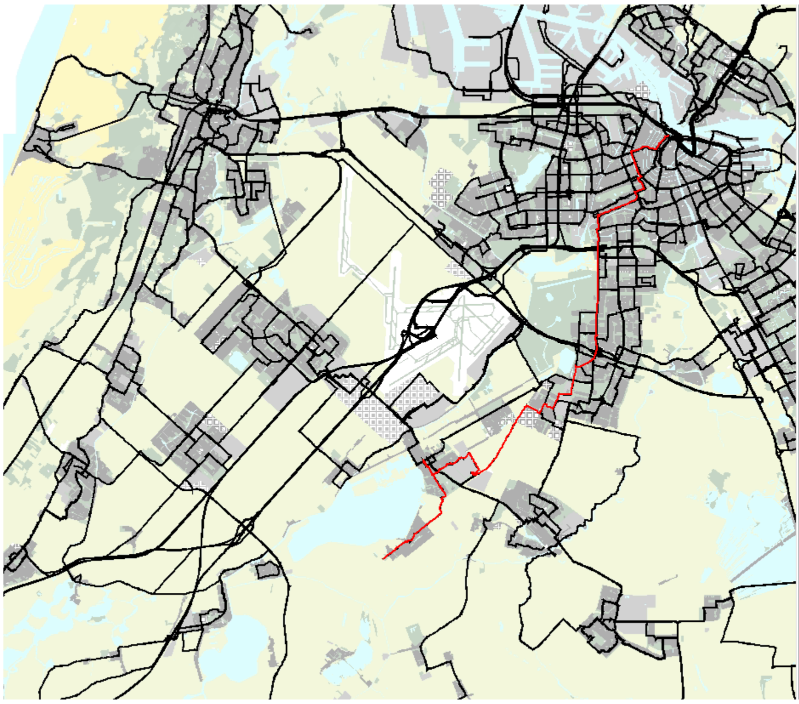


Figure 82: Route of Line 172 in VENOM

Base Alternative

The base alternative captures line 172 without alteration in the service and performance of the line. As explained, the service of line 172 in VENOM is first changed for it to correspond with the service of the line in 2015. For line 172, the route of VENOM was compared to the route of line 172 and altered. The following stops have been added to the model:

- BVFH Noord
- BVFH Oost
- Marnixstraat

The following bus stops have been turned off in the model (the bus passes by the stop, but does not stop there):

- Plantanus
- ‘t Huis aan de Poel

Two stops have different names in the model as opposed to the real life service:

- Populierenlaan is actually Lindenlaan (though both exist in real life as well)
- Hobemanstraat is actually Rijksmuseum (though both exist in real life as well)

Finally, around bus stops Weldam, Cannenburgh and Westijkplein, a new neighbourhood has been built. These three stops are not represented yet in the model, or are represented wrong. As the matrix cubes of OmniTRANS are not altered for this research, the old schedule that of the model, is used. This means that stops Nieuwoosteinde, Boschplaat and Westwijkplein are used instead.

Frequency Alternative

In the frequency alternative, the base alternative is altered and the frequency of the service is increased. The frequency of the service is increased to 10 busses per hour for the morning rush hour (as the model is only run for the morning rush hour). The frequency in the base alternative was 4 times per hour for the entire day. In real life, this frequency actually is 6 busses per hour during rush hour, and 3 in off-peak periods. A fixed frequency of 4 buses per hour is used to model line 172 over the entire day, thus no differences are assumed between peak and off-peak hours.

The frequency has been changed in the attribute editor for both directions of line 172 (Figure 83)

frequency	
frequency (1:Os)	10,00
frequency (2:Rd)	10,00
frequency (3:As)	10,00

Figure 83: Changes in Attribute Editor (frequency)

Speed Alternative

For the speed alternative, the speed is increased by adding dedicated infrastructure on the route. The scorecard in chapter 6 has showed the differences in speeds between R-Net and Comfortnet services. All R-Net lines have a commercial speed well above 30 kilometres per hour (except for line 340), whereas the speed of line 172 only is 22 kilometres per hour. Speeds could be increased through the construction of dedicated infrastructure. For line 172, the speed can be increased to a commercial speed of 30 kilometres per hour when XX kilometres of dedicated infrastructure is built. This infrastructure is built between Kudelstaart and Aalsmeer, between Aalsmeer and Ouderkerk aan de Amstel, and between Ouderkerk aan de Amstel and Amstelveen.

The resulting table from the Transit Line editor is presented in the table below.

Stop	Stop Tag	Stop Type	Travel Time	Default time	Assignment time	Dwell Time	Cum Time	Average Speed	Length
546:Centraal Station		Normal							
16876:Nieuwezijds Kolk		Normal	0,66513014	0,4068	0	0	0,66513014	30,58048058	0,339
545:Dam		Normal	0,78873837	0,4824	0	0	1,45386851	30,58048248	0,402
2736:Westermarkt		Normal	1,18114567	0,72240001	0	0	2,63501406	30,58047867	0,602
5318:Marnixstraat		Normal	0,76911807	0,47039998	0	0	3,40413213	30,58047867	0,392
539:Rozengracht		No stop	0,22955815	0,14040001	0	0	3,63369036	30,5804863	0,117
538:Rozengracht		No stop	0,03924072	0,024	0	0	3,67293119	30,58047867	0,02
7382:Elandsgracht		Normal	0,75342178	0,46079999	0	0	4,42635298	30,58048058	0,384
7360:Elandsgracht		No stop	0,07063329	0,0432	0	0	4,49698639	30,58047867	0,036
7238:Raamplein		No stop	0,52582562	0,32159999	0	0	5,02281189	30,58048058	0,268
7394:Raamplein		No stop	0,26291281	0,16080001	0	0	5,28572464	30,58048058	0,134
540:Leidseplein		Normal	0,70044678	0,42840001	0	0	5,98617125	30,58048058	0,357
4627:Stadhouderskade		No stop	0,28057116	0,17160001	0	0	6,26674223	30,58047867	0,143
232:Hobbemastraat		Normal	0,91627073	0,56040001	0	0	7,18301296	30,58048248	0,467
5658:Van Baerlestraat		No stop	0,72791517	0,4452	0	0	7,91092825	30,5804863	0,371
1847:Museumplein		Normal	0,50228119	0,30719998	0	0	8,41320992	30,58047867	0,256
963:Jac. Obrechtstraat		Normal	0,57880056	0,35399997	0	0	8,99201012	30,58048058	0,295
3889:Emmastraat		Normal	0,89665031	0,54840004	0	0	9,88866043	30,58048439	0,457
5025:Valeriusplein		Normal	0,75145966	0,45959997	0	0	10,64012051	30,58048248	0,383
1016:Valeriusplein		No stop	0,09613976	0,0588	0	0	10,73626041	30,58048248	0,049
6149:C.Krusemanstraat		No stop	0,92608094	0,56639999	0	0	11,66234112	30,58048058	0,472
4126:Haarl'meerstation		No stop	0,14911473	0,0912	0	0	11,81145573	30,58048248	0,076
1710:Haarl'meerstation		No stop	0,03924072	0,024	0	0	11,85069656	30,58047867	0,02
2909:Haarl'meerstation		Normal	0,15107676	0,0924	0	0	12,00177288	30,58048058	0,077
3384:Stadionplein		Normal	0,93392903	0,57120001	0	0	12,93570232	30,58048248	0,476
236:IJsbaanpad		Normal	0,80443466	0,49199998	0	0	13,7401371	30,58048248	0,41
2952:Amstelveenseweg		Normal	0,46696454	0,28560001	0	0	14,20710182	30,58048058	0,238
1306:VU medisch centrum		Normal	0,92019469	0,56280005	0	0	15,12729645	30,58048439	0,469
3949:Koenenkade		Normal	0,98101771	0,60000002	0	0	16,10831451	30,5804882	0,5
5859:Van Nijenrodeweg		Normal	0,5591802	0,34200001	0	0	16,66749382	30,58048248	0,285
5612:Bolestein		No stop	0,90253651	0,55199999	0	0	17,57003021	30,58048058	0,46
3759:Kalfjesl./Amstelv.wg		Normal	0,41987568	0,2568	0	0	17,98990631	30,58048058	0,214
4170:Graaf Florislaan		Normal	1,09677804	0,67079997	0	0	19,08668518	30,58048248	0,559
1846:Dijkgravenlaan		Normal	0,69456059	0,42480001	0	0	19,78124619	30,5804863	0,354
1096:Kruiskerk		Normal	0,50816727	0,31080002	0	0	20,28941345	30,58048248	0,259
4124:Heemraadschapslaan		Normal	1,02222073	0,62520003	0	0	21,31163406	30,58048058	0,521
5934:Busstation		Normal	0,73380142	0,4488	0	0	22,04543495	30,58048058	0,374
2412:Busstation		No stop	0,23348227	0,1428	0	0	22,27891731	30,58048058	0,119
5380:Keizer Karelplein		Normal	0,94962543	0,5808	0	0	23,22854233	30,58047867	0,484
4729:Icaruslaan		Normal	0,40025532	0,2448	0	0	23,62879753	30,58048058	0,204
189:Populierenlaan		Normal	0,44342011	0,2712	0	0	24,07221794	30,58048058	0,226
1443:'t Huis a/d Poel		No stop	0,40025532	0,2448	0	0	24,47247314	30,58048058	0,204
5959:Handweg		Normal	1,08108163	0,66119999	0	0	25,55355453	30,58048439	0,551
1636:Bovenkerkerweg		No stop	0,79658651	0,48719999	0	0	26,35014153	30,58048439	0,406
2850:Bovenkerkerweg		Normal	0,2786091	0,17039999	0	0	26,62874985	30,58047867	0,142
2236:Sacharovlaan		Normal	1,62848973	0,99600005	0	0	28,2572403	30,58048248	0,83
7442:Sacharovlaan		No stop	0,5395599	0,33000001	0	0	28,79680061	30,58047867	0,275
1873:Westwijkplein		Normal	1,25701094	0,76880002	0	0	30,05381203	26,06182671	0,546
2031:Boschplaat		No stop	1,41070366	0,86280006	0	0	31,46451569	22,66953659	0,533
2135:Boschplaat		Normal	0,13538048	0,0828	0	0	31,59989548	30,58047867	0,069
690:Nieuw Oosteinde		Normal	1,73689258	1,06229997	0	0	33,33678818	40,45155334	1,171
5706:BVFH Ingang B4-B5		Normal	3,49414134	2,13704991	0	0	36,8309288	47,49664307	2,766
16875:BVFH Ingang Oost		Normal	2,01081038	0,8179754	0	0	38,84173965	20,33944702	0,681646
16874:BVFH ingang NOORD		Normal	1,09970391	0,5439328	0	0	39,9414444	24,73087692	0,453277
4829:BVFH Ingang C1-D3		Normal	0,73115176	0,45371199	0	0	40,67259598	31,02721024	0,378093
2774:P.F.von Sieboldlaan		No stop	0,17462122	0,1068	0	0	40,84721756	30,58047485	0,089
5246:P.F.von Sieboldlaan		Normal	0,23152024	0,1416	0	0	41,07873917	30,58048058	0,118
185:Mendelstraat		Normal	0,5670284	0,3468	0	0	41,64576721	30,58047867	0,289
3875:Zwarteweg/N201		No stop	0,34531832	0,2112	0	0	41,99108505	30,58048058	0,176
1163:Zwarteweg		Normal	0,69456077	0,42479998	0	0	42,68564606	30,58047485	0,354
1866:Gloxiniastraat		Normal	0,43753397	0,2676	0	0	43,12318039	30,58048248	0,223
3082:Gloxiniastraat		No stop	0,13341844	0,0816	0	0	43,25659943	30,58048248	0,068
2505:Gloxiniastraat		No stop	0,10202587	0,0624	0	0	43,3586235	30,58048058	0,052
1715:Hortensiaplein		Normal	0,71614307	0,43799999	0	0	44,07476807	18,34828949	0,219
2505:Gloxiniastraat		No stop	0,71614307	0,43799999	0	0	44,79091263	18,34828949	0,219
3082:Gloxiniastraat		No stop	0,10202587	0,0624	0	0	44,89293671	30,58048058	0,052
1866:Gloxiniastraat		Normal	0,13341844	0,0816	0	0	45,02635574	30,58048248	0,068
1163:Zwarteweg		Normal	0,43753397	0,2676	0	0	45,46389008	30,58048248	0,223
5127:Beethovenlaan		Normal	1,1634872	0,71160001	0	0	46,62737656	30,5804863	0,593
1303:Mozartlaan		Normal	1,26878321	0,77600002	0	0	47,89616013	18,34828949	0,388
7284:Legmeerdijk		Normal	2,03397703	1,24400008	0	0	49,93013763	29,02687645	0,984
6260:De Rietlanden		Normal	1,73640168	1,06200004	0	0	51,66653824	30,58048248	0,885
3502:Einsteinstraat		Normal	0,88880223	0,54360002	0	0	52,55533981	30,58048248	0,453
3501:Schweitzerstraat		No stop	0,58861077	0,36000001	0	0	53,14395142	30,58048058	0,3
5722:Schweitzerstraat		Normal	0,11445209	0,07	0	0	53,25840378	18,34828758	0,035
4896:Gravin Aleidstraat		Normal	1,18245363	0,72320002	0	0	54,44085693	19,68787575	0,388
5347:Calslager Bancken		Normal	1,33091426	0,81400001	0	0	55,77177048	18,34828949	0,407
2067:Bilderdammerweg		Normal	1,22823441	0,75119996	0	0	57,00000381	30,58048058	0,626
Total			57	34,33	0	0	57	29,98	28,48

Stop Density Alternative

Although no significant relation has been found between the stop density and the catchment area, this alternative is researched as an extra check. This alternative is modelled to see what would happen to the service if one of the characteristics of high quality services is imposed on the network.

For this alternative, several stops are chosen to be no longer served by line 172. The choice for which stops are discarded is based on the stop usage of the different stops that has already been presented in appendix I.

The resulting table from the transit line editor, which depicts the stops that are served, is presented in the table below.

Stop	Stop Type
546:Centraal Station	Normal
16876:Nieuwezijds Kolk	No stop
545:Dam	Normal
2736:Westermarkt	No stop
5318:Marnixstraat	Normal
539:Rozengracht	No stop
538:Rozengracht	No stop
7382:Elandsgracht	Normal
7360:Elandsgracht	No stop
7238:Raamplein	No stop
7394:Raamplein	No stop
540:Leidseplein	Normal
4627:Stadhouderskade	No stop
232:Hobbemastraat	No stop
5658:Van Baerlestraat	No stop
1847:Museumplein	Normal
963:Jac. Obrechtstraat	No stop
3889:Emmastraat	No stop
5025:Valeriusplein	Normal
1016:Valeriusplein	No stop
6149:C.Krusemanstraat	No stop
4126:Haarl'meerstation	No stop
1710:Haarl'meerstation	No stop
2909:Haarl'meerstation	Normal
3384:Stadionplein	No stop
236:IJsbaanpad	No stop
2952:Amstelveenseweg	Normal
1306:VU medisch centrum	Normal
3949:Koenenkade	No stop
5859:Van Nijenrodeweg	Normal
5612:Bolestein	No stop
3759:Kalfjesl./Amstelv.wg	No stop
4170:Graaf Florislaan	Normal
1846:Dijkgravenlaan	No stop
1096:Kruiskerk	Normal
4124:Heemraadschapslaan	Normal
5934:Busstation	Normal
2412:Busstation	No stop
5380:Keizer Karelplein	No stop
4729:Icaruslaan	No stop
189:Populierenlaan	Normal
1443:'t Huis a/d Poel	No stop
5959:Handweg	Normal
1636:Bovenkerkerweg	No stop
2850:Bovenkerkerweg	No stop
2236:Sacharovlaan	Normal
7442:Sacharovlaan	No stop
1873:Westwijkplein	Normal
2031:Boschplaat	No stop
2135:Boschplaat	No stop
690:Nieuw Oosteinde	Normal
5706:BVFH Ingang B4-B5	Normal
16875:BVFH Ingang Oost	No stop
16874:BVFH ingang NOORD	No stop
4829:BVFH Ingang C1-D3	No stop
2774:P.F.von Sieboldlaan	No stop
5246:P.F.von Sieboldlaan	Normal
185:Mendelstraat	No stop
3875:Zwarteweg/N201	No stop
1163:Zwarteweg	Normal
1866:Gloxiniastraat	No stop
3082:Gloxiniastraat	No stop
2505:Gloxiniastraat	No stop
1715:Hortensiaplein	Normal
2505:Gloxiniastraat	No stop
3082:Gloxiniastraat	No stop
1866:Gloxiniastraat	No stop
1163:Zwarteweg	Normal
5127:Beethovenlaan	No stop
1303:Mozartlaan	No stop
7284:Legmeerdijk	No stop
6260:De Rietlanden	Normal
3502:Einsteinstraat	No stop
3501:Schweitzerstraat	No stop
5722:Schweitzerstraat	Normal
4896:Gravin Aleidstraat	No stop
5347:Calslager Bancken	No stop
2067:Bilderdammerweg	Normal

Speed and Frequency Alternative

For this alternative, speed and frequency are adjusted in accordance with the speeds and frequency as presented in the corresponding alternatives.

Speed, Frequency and Stop Density Alternative

For this alternative, speed and frequency and used stops are adjusted in accordance with the speeds and frequency as presented in the corresponding alternatives.

Alternatives of Line 300

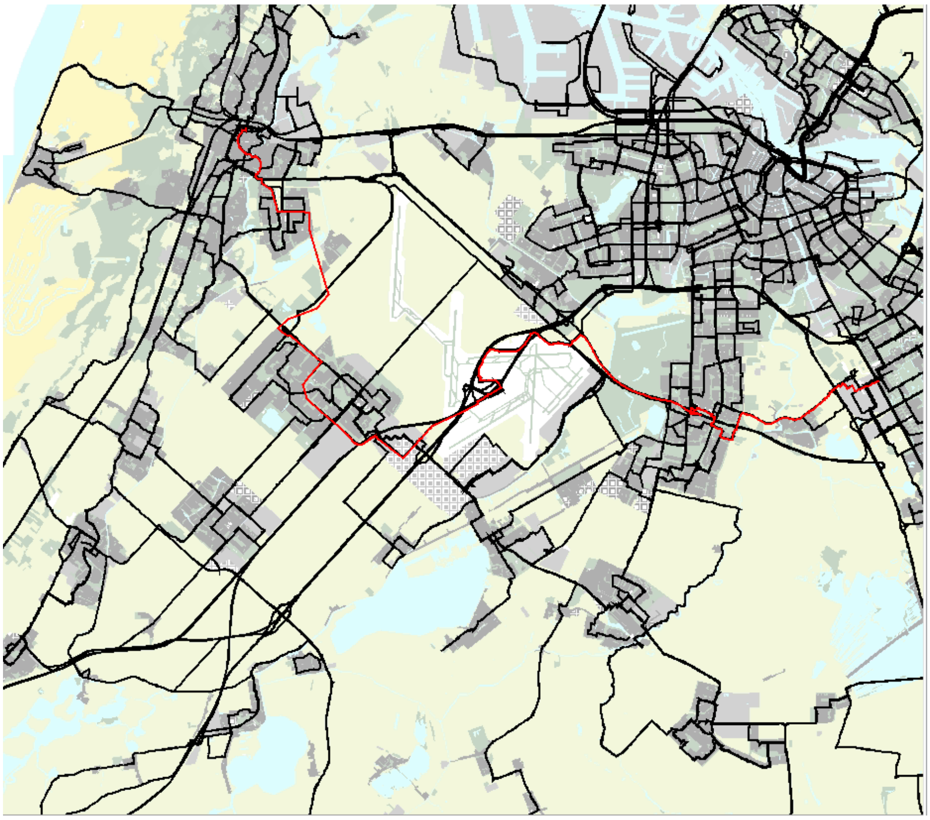


Figure 84: Line 300 in VENOM

Base Alternative

The base alternative captures line 300 without alterations in the service and performance of the line. The representation of the line is altered for it to correspond with the service of line 300 in real life.

The changes that have been made to the route of line 300 include the rerouting of the line via the south of Amstelveen Bus station instead of via metro station Oranjebaan.

Express Service Alternative

An express service has been added to the normal service of line 300. Based on an analysis of stop usage (as presented in appendix G), several stops have been deemed to be more important due to the number of passengers they serve and their strategic position (e.g. next to a metro or train station). This leads to the service of 300E as presented in the table below.

Stop	Stop Type
4478:Parklaan/Station uitstap	Normal
817:Nassaulaan	No stop
3991:Nassaulaan	No stop
4253:Raaks	No stop
806:Centrum/Verwulft	No stop
4538:Turfmarkt	No stop
7424:Langebrug dummy	No stop
3420:Byzantiumstraat	No stop
1357:Graafschapstraat	No stop
2727:Schipholweg/Europaweg	No stop
1432:Schipholweg/Europaweg	No stop
7425:Europaweg	No stop
6362:Europaweg/KG lok.Zuid	No stop
6093:Winkelc. Schalkwijk	No stop
7429:Schalkwijk Centrum	No stop
16736:Vijfhuizen	No stop
16873:Hoofddorp - Expo Haarlemmermeer	No stop
403:Spaarne Ziekenhuis	No stop
7406:Spaarne Ziekenhuis	No stop
7457:Overbos	No stop
7456:Bornholm	No stop
7407:Toolenburg	No stop
7408:Graan voor Visch	No stop
7409:Station	Normal
7410:Beukenhorst	No stop
4625:De Hoek	No stop
263:Schipholgebouw	No stop
4324:Vrachtgebouw	No stop
5778:Plaza/NS	No stop
7411:Plaza/NS	Normal
2:Sleepterrein	No stop
4364:Parkeerterrein P40	No stop
6068:Elzenhof	No stop
5694:Loevesteinse Dw.weg	No stop
2994:Hotel Ibis	No stop
5563:Schiphol Noord	No stop
2412:Busstation	No stop
3936:Busstation	Normal
1179:Binnenhof	No stop
2298:Ouderkerkerlaan	No stop
2299:Ziekenhuis	No stop
6349:Ziekenhuis (LvHM)	No stop
1214:Langerhuize	No stop
3694:Brug/Amsteldijk	No stop
4307:Brug/Amsteldijk	No stop
5813:Brug/Hoger Einde	No stop
2164:J. van Ruisdaelweg	No stop
3640:Ventweg	No stop
6032:Keienbergweg	No stop
1282:Holterbergweg	Normal
3475:Gebouw Atlas	No stop
3075:Hoogoorddreef/Atlas	Normal

Tunnel Alternative

The final alternative includes a tunnel under the city centre of Haarlem. After an analysis of the speeds in the different links of line 300 in VENOM, this region has been concluded to be a useful alteration region that allows for the increase of the commercial speed of the entire line. Figure 85 presents the current situation and routing of line 300 in the city centre of Haarlem.

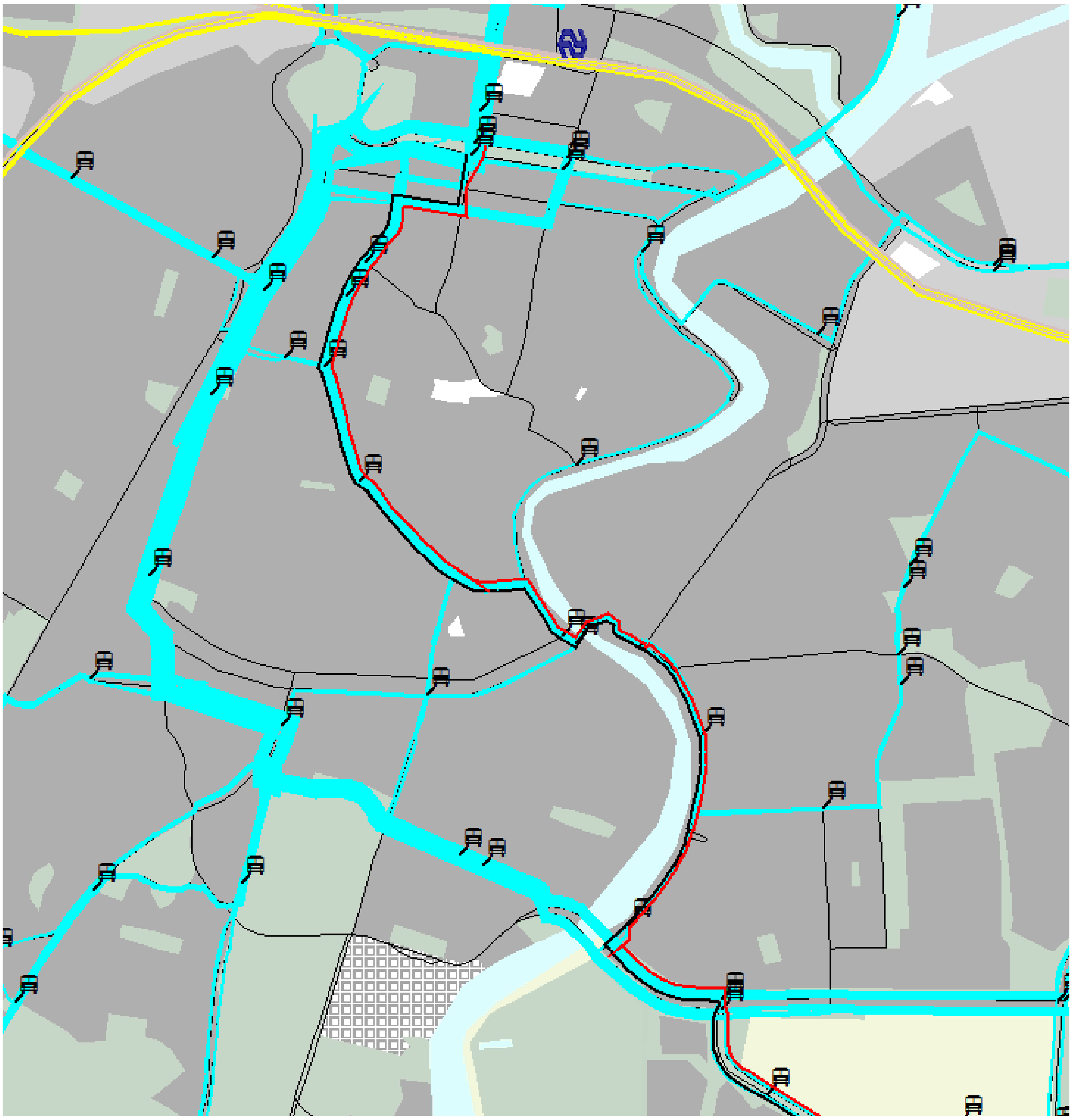


Figure 85: Current situation in Haarlem Centre

Figure 86 presents the tunnel in the area. The tunnel has a total length of 1600 metres. An extra stop is added to allow for people from the centre of Haarlem to board the bus. The speed in the tunnel has been modelled after the Abdijtunnel that connects de Hoek with Schiphol, and is initially set at 50 km/h.

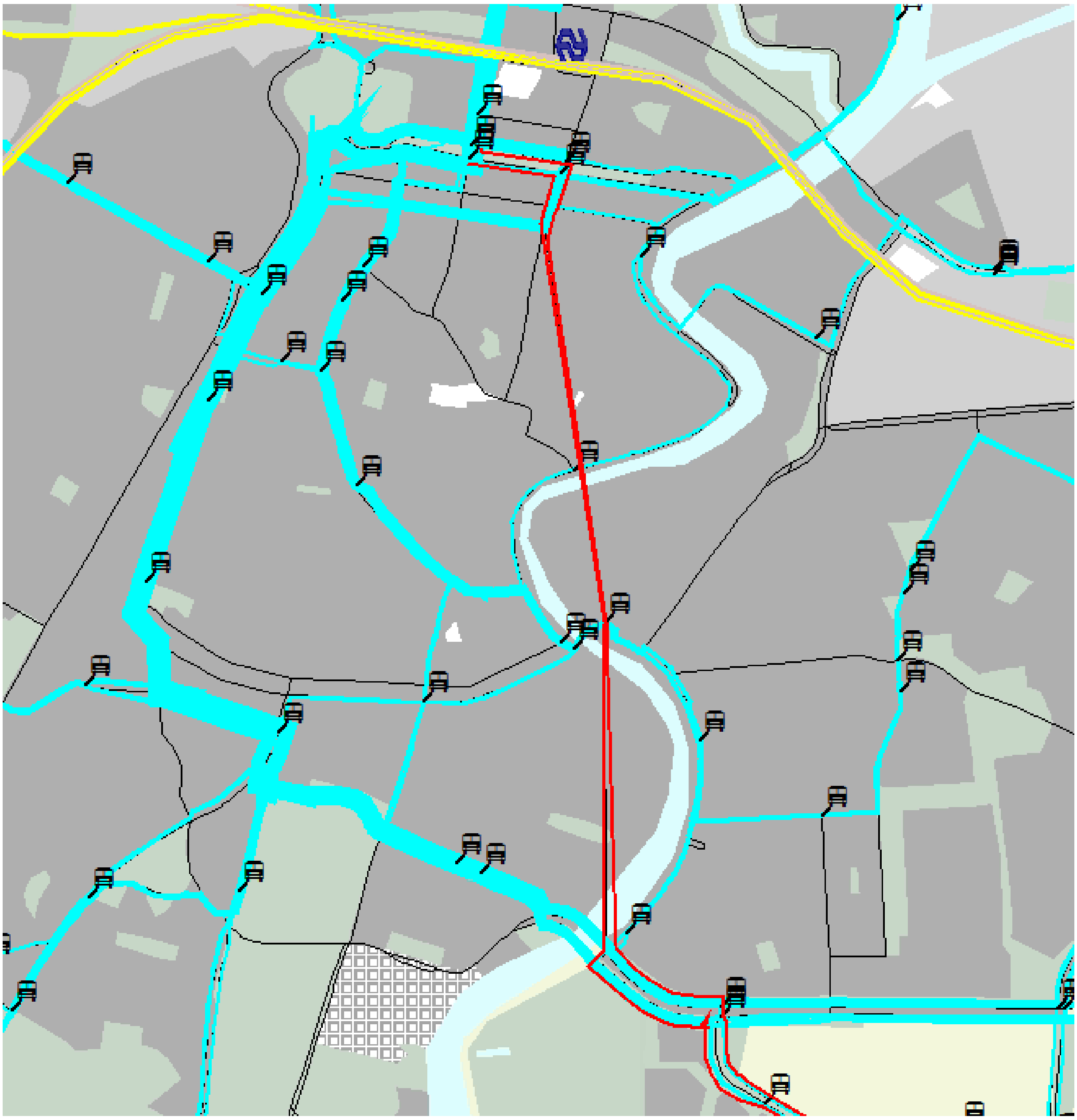


Figure 86: Location of the tunnel in the city centre of Haarlem

L. Cost-Benefit Analysis

Table 190: Calculation of Investment Costs

Measure	Year	Price (€)	Inflation Correction	length (km)	price per km
Bus stop	2015	27000	27000	-	-
Infrastructure	2002	231600000	266050000	40	6651250
Tunnel	2002	62000000	36134500	1,8	20074722,22

Table 191: Calculations of Travel Time Gains for Alternatives of Line 172

Alternative	Travel Time (hours)	Delta time (hours)	Existing Passengers Base (#)	Total Passengers (#)	New Passengers (#)	VoT (€/hour)	Rule of Half (€/hour)	Total Travel Gains (€)
Base	1,076	0,000	2436667	2436667	0	6,28	3,14	0
Frequency	1,160	-0,084	2436667	6915425	4478758	6,28	3,14	-2461590
Speed	0,945	0,131	2436667	7960991	5524324	6,28	3,14	4282663
Stops	1,137	-0,060	2436667	1742183	-694484	6,28	3,14	-793658
Freq & St	1,157	-0,081	2436667	5232512	2795845	6,28	3,14	-1955051
Frequ-St-Sp	1,030	0,046	2436667	16408753	13972085	6,28	3,14	2724456

Table 192: Calculations of Travel Time Gains for Alternatives of Line 300

Alternative	Travel Time (hours)	Delta time (hours)	Existing Passengers Base (#)	Total Passengers (#)	New Passengers (#)	VoT (€/hour)	Rule of Half (€/hour)	Total Travel Gains (€)
Base	0,819	0,000	8079512	8079512	0	6,28	3,14	0
Plus Express	0,116	0,703	8079512	7683203	-396309	6,28	3,14	34782525
Tunnel	0,868	-0,049	8079512	9642994	1563482	6,28	3,14	-2745930

Table 193: Cost-Benefit Analysis Line 172 (in millions of euros)

		Base	Frequency	Speed	Stops	Frequency and speed	Frequency, speed, stops
Costs							
Investment Costs		0,0	1,5	68,0	0,8	68,0	68,0
Operational Costs	€110/bus/hour	2,1	93,3	12,2	62,8	12,7	12,7
Benefits							
Operator Benefits							
Income from Operations	€0,17/traveller kilometre	3,6	169,3	62,3	87,2	6,4	13,7
Stadsregio Subsidies	Max 0,5*operational costs		0,0	0,0	0,0	6,4	6,4
Passenger Benefits							
Travel Time Gains			-38,2	24,5	-23,3	-1,8	-2,0
External Effects							
Emissions	PM1	0	-	-	0	-	-
Noise	PM2	0	-	-	0	-	-
Traffic Safety	PM3	0	-	-	0	-	-
TOTAL			36,2	12,6	0,3	-69,8	-62,6

Table 194: Cost-Benefit Analysis Line 300 (in millions of euros)

		Base	Express Service	Tunnel
Costs				
Investment Costs		0,0	0,0	34,1
Operational Costs	€110/bus/hour	6,0	130,6	34,3
Benefits				
Operator Benefits				
Income from Operations	€0,17/traveller kilometre	10,0	81,6	89,5
Stadsregio Subsidies	Max 0,5*operational costs		0,0	0,0
Passenger Benefits				
Travel Time Gains			540,3	-15,7
External Effects				
Emissions	PM1	0	-	-
Noise	PM2	0	-	+
Traffic Safety	PM3	0	-	+
TOTAL			491,3	5,4

Table 195: Average distances travelled

Line number	172	300
Average travel distance (km)	7,275	8,637