The Evaluation of the Pilot **Breng Flex**

An Urban Demand Responsive Transport (DRT) Service around Arnhem and Nijmegen

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Abstract

Demand Responsive Transport (DRT) services provide transport “on demand” for passengers using fleets of vehicles scheduled to pick up and drop off people in accordance with their needs. For the urban DRT service Breng Flex this means a service using small buses and electric cars with a flexible routing and a personalized service. Urban DRT services aimed at the general population and not at determined groups (such as the disabled or the elderly) is not fully understood. About the pilots in the past is not much publicly available research. How does urban DRT serve the transportation needs taking the existing public transportation options into account? This thesis will contribute to the understanding of urban DRT by means of the pilot Breng Flex, an urban DRT around Arnhem and Nijmegen started in December 2016. The data is available for the rides from December 18th 2016 till May 18th 2017.The initial evolution of this service is analyzed, including the temporal analysis of the performance and usage, and a spatial analysis. After analyzing the current performance of Brengflex, it is compared with the timewise performance with the regular public transport alternatives.

The urban DRT service Breng Flex around Arnhem and Nijmegen shows that passengers have a large variety of routes, so this service can accommodate different individual mobility needs. The demand of Breng Flex starts early in the morning before the operating hours of the regular public transport. The demand during the day shows, in contrast to regular public transport, no significant higher demand during the rush hours. The demand of Breng Flex stays noticeable similar throughout the day. 20 % of the rides starts or ends at a train station, showing the potential usage of Breng Flex as a leg of a longer journey. The demand of Breng Flex is still growing rapidly with an average of 54 rides per day in March 2017, increasing to 89 rides per day in April 2017, an increase of over 60 %. The existing capacity of the vehicles is still sufficient, based on the constant average waiting time of around 10 minutes per ride. Over 80 % of the users of Breng Flex have used it again and the share of the rides taken by the regular users is high with 87 % in April. This research suggests that the performance of Breng Flex, an urban DRT service, is sufficient to be an attractive alternative for the public transport for passengers.

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1) Introduction

'Demand Responsive Transport (DRT) services provide transport "on demand" for passengers using fleets of vehicles scheduled to pick up and drop off people in accordance with their needs' (2). Typically this means a service using small buses or cars with a flexible routing and a personalized service (3). Historically, DRT started as paratransit used for door-to-door dial-a-ride services provided for restricted usage, usually for the disabled and elderly. The scheduling offered clients some flexibility in the route and schedule, but with manual development of the schedules, the rides had to be reserved days in advanced (3).

Nowadays routes can be reworked real-time to efficiently service extra clients on short notice, making it possible to offer more convenient DRT services at more affordable prices (4). DRT services provides an easy way to travel. It is not needed to check the travel times in advance, more departure options are available, transfers aren't needed anymore and a seat is guaranteed because it is reserved. Also it makes traveling feel safer, because of the smaller buses and the direct contact with the driver (5).

Urban DRT for the masses is still not fully understood. The pilots in the past were mostly paratransit. There were, however, some urban DRT pilots (Bridj (Boston, 2014 - 2017)(6) and Kutsuplus (Helsinki, 2012 - 2015)(7)) and more recently Abel (ongoing since 2016)(8) started to provide urban DRT services. Both Bridj and Kutsuplus were ended due to financial reasons. About Bridj and Abel is not much publicly available, but about Kutsuplus is more publicly available in the form of a final report (7). The fleet of Kutsuplus included 15 vehicles. Booking in advance was not possible, due to the small fleet and capacity. Users of Kutsuplus had to put money into a separate e-wallet to pay for the service, this was inconvenient for the passengers. Another inconvenient characteristic was the booking system. This was in the beginning only available on a website. Later, booking was also available by app. A smart feature of the booking system was the different levels rides, with changing fees during the day and based on the "guaranteed" arrival time. This feature was used to smoothen the demand of Kutsuplus during the day.

The evaluation of an urban DRT service in this thesis is interesting for the different parties who would like to know more about the background of DRT services and about the assessment of the performance of an urban DRT service in terms of convenience and reliability. There is still limited knowledge about how services are used and how they perform time-wise in comparison to regular public transportation services and this thesis helps in filling the gap. The evaluation provides usable insights on the performance of an urban DRT service and to get knowledge on this prospective public transportation service. The operator could use these points to strategically improve the DRT service and market it using its strengths. DRT can be a feasible alternative to fixed lines in the evenings, when public transport demand drops. By using DRT systems, exploitation costs can be reduced during these off-peak times.

For provinces and municipalities this thesis is also very interesting. In the rest of the Netherlands many municipalities are following the developments of Breng Flex with interests (among them are Eindhoven, Den Haag, Zeeland, Rotterdam and Haarlem) and also worldwide cities (Stockholm, Paris, Tampa and Sydney) haves shown their interest in this form of flexible public transportation (5). Urban DRT services could be a way to make public transportation more attractive. These shared rides (DRT) in comparison to an individual ride would mean fewer vehicle kilometers per passenger, less parking space is needed, less traffic congestion and, therefore, less waiting time for citizens and reduced emissions (7). Also Reducing social exclusion and improving social service transport is increasingly interesting for the government (2). Also to make small villages easily accessible it is no longer needed to have a big bus driving by. Only when needed small energy efficient buses have to go there. Using the methodology in

this thesis it is possible compare the, for example yearly, performance of the DRT service and see the strengths and weaknesses.

This thesis will contribute to the understanding of urban DRT services by means of the pilot Breng Flex, an urban DRT around Arnhem and Nijmegen. Breng Flex is carried out by Hermes, a subsidiary of Connexxion. The evaluation of Breng Flex for the Breng Knowledge Center is done as part of the SCRIPTS project (Smart Cities Responsive Intelligent Public Transport Systems) (9). For the SCRIPTS project different universities, and other partners are collaborating to develop knowledge that helps address issues relating to amongst others mobility and transport (10).

Based on research seems that customers considered 4 euro per ride as being a fair price for the service (4). At the current price point of € 3,50 per ride, Breng Flex should be a viable and attractive alternative for more people in comparison to earlier more expensive alternatives, which asked comparative fees like taxis. The evaluation of Breng Flex in this thesis focuses on two things. The first is to analyze the initial evolution of the usage and timewise performance of Breng Flex. The second is to analyze the time-wise gain for the passengers in comparison to regular public transportation alternatives, because this is an important factor for passengers when choosing a transport mode (11). The main question that follows from these points and will be answered is:

How does the urban DRT service Breng Flex serve the transportation needs of the cities Arnhem and Nijmegen, taking into account the existing public transportation options?

The main question is answered in different steps. Firstly, the usage and performance of Breng Flex is evaluated. Based on these evaluations the growth of Breng Flex can be monitored. Where is a demand for this kind of DRT services?

a) How is the performance and the usage of the urban DRT system Breng Flex? How has the usage temporally evolved?

Secondly, are trips with Breng Flex combined with train rides? If this is the case, this would mean that Breng Flex is used as a leg in longer public transport trips.

b) How often has Breng Flex been used as a first/last mile to/from the train stations?

Lastly, how does Breng Flex perform temporally in comparison to public transportation alternatives? How large is the actual time gain or loss for the passengers who chose to use Breng Flex?

c) What are the perceived and real difference in times when using Breng Flex in comparison to existing public transportation options?

2) Methodology

Firstly the data obtained from Breng Flex will be explained and after that the methodology and the design approach will be explained per sub question. In general the following steps are processed:

Data: What is the data needed for each question? What other data would be relevant?

Analysis: What analyses is useful for each question? Which graph is suitable for the data (e.g. histogram, circle diagram)?

Based on the data, the descriptive statistics can be calculated. 'Descriptive statistics are numbers that are used to summarize and describe data' (12). Using Excel, the mean, median, standard deviation, minimum, maximum, power are calculated. The 10^{th}, 25^{th}, 50^{th}, 75^{th} and 90^{th} percentile values are also calculated. Histograms will be made using the Analysis ToolPak in Excel (13). The bins are chosen so if a histogram shows [0, 1, 2, 3] on the horizontal axis, of the column above the 1 shows the frequency of the data that is ranging from 0.50000 to 1.49999, with an accuracy of 5 decimals. This is stated explicitly because Excel makes different histograms out of the box.

Evaluation 1: What evaluations are useful? How will these evaluation be performed? What percentages are interesting?

Comparison: What factors could pose a difference with the whole dataset? Argue why these are possible factors. What is the data needed for these comparisons?

Here is a list of factors, with the data used to sort the data, that will be evaluated in different sub questions:

- Arnhem versus Nijmegen; Breng Flex may have a higher acceptance among users in one of the two cities
    - Data: location (Arnhem or Nijmegen)
- Time of the day (e.g. between 07.00 and 08.00), based on the booking time; during rush hours the rides might have a longer in-vehicle time than expected due to the high amount of traffic on the roads.
    - Data: booking time
- Day of the week; it is likely that the traffic is lighter in weekends. So the chances of delays because of traffic jams are slimmer.
    - Data: day of the week
- Stops; depending on where the vehicles wait for new passengers some stops might have longer waiting times. If stops are near train stations, then Breng Flex might be used as a first/last mile solution.
    - Data: names of the stops

Evaluation 2: What factors significant influence the previous evaluation? How could this be used as an advantage? What are the limitations posed by these factors?

For relevant datasets per factor in the comparison (e.g. only the data of Mondays) a t-test is done, using Excel's Analysis ToolPak (14), to test if the factors are significant for the means.

2.1) Data

Firstly more information is provided about the circumstances in how the urban DRT service Breng Flex operates, to clarify where the data comes from. Thereafter the dataset obtained will be explained; including the limitations of the dataset.

2.1.1) Breng Flex

The evaluation on an urban DRT service will be done using the data from the pilot Breng Flex. Breng Flex is a new DRT pilot in the area of Arnhem (including Velp and Rozendaal) and Nijmegen (including 'Berg en Dal', Oosterhout and Wijchen) (Figure 1). Both cities are middle-sized with respectively around 155,000 and 175,000 citizens (15). Characteristic for these two areas are the rivers dividing different parts of the areas. The usage of Breng Flex might be higher since some fixed lines were cancelled and as an alternative passengers could now use this flexible form of transport (16). Both regions are not connected at this stage of the pilot. So that different tariffs are not needed and it is possible to compare the both independent areas with each other. The pilot started on 18 December 2016 (4) with a fleet of ten taxi buses and eight electric vehicles. In each area five taxi buses and four electric vehicles are available (4).

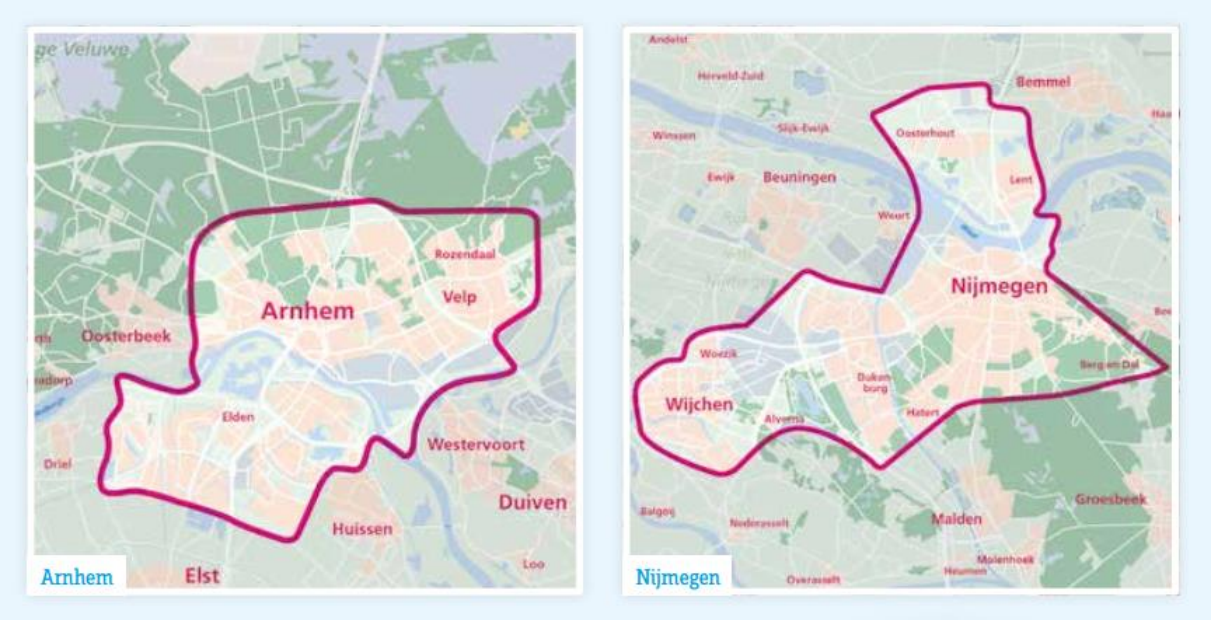

Figure 1 Breng Flex in the area Arnhem (including Velp and Rozendaal) and Nijmegen (including 'Berg and Dal', Oosterhout and Wijchen)

Breng Flex is a transport service that transports people from stop to stop. In each area more than 250 pickup and drop off points are available. All the regular bus stops are available and extra virtual stops are also added (17). Based on the reservations by passengers the vehicles stop at the requested stops. During the rides it is possible that the vehicles make small detours to pick up other passengers. There is a fixed price for a ride, € 3,50 per person. Every day of the week Breng Flex is available till 24:00. The starting times are 06:30 on weekdays, 08:00 on Saturdays and 09:00 on Sundays (18).

2.1.2) Dataset

The dataset contained the rides of almost six months, from December 15th 2016 (the first few days are probably a closed-beta) to May 18th 2017. Per trip a lot of data is available. In short, the available data is summed up:

- Company information; including a unique ID per sub-contractor to keep track.
- Customer information; including an anonymous unique ID per customer to keep track.
- Vehicle information; including a unique ID per vehicle to keep track.
- Driver information; including an anonymous unique ID per driver to keep track. Also with shift times, log on and log off times.
- Payment information; including the payment method (e.g. Ideal, credit card), the fee and discount information (Regular, Discount, Free)
- Customer ratings; available if the customer has reviewed the trip.
- Last updated date; timestamp of when the data is extracted from their database.
- Trip information; including a unique ID per trip to keep track. Other data in this category include times accurate to the second and locations in longitudes and latitudes.
    - Trip status; The status are as follows: "customer arrived", "driver cancelled because of client", "driver cancelled because of driver" and "refunded".
    - Number of passengers; Reservations could be made for one to five passengers at once. For more passengers multiple people should make a reservation.
    - Booking time; Date and time of the reservation. Reservations in advance are not available.
    - Departure time; Date and time of the pick up of the passenger(s).
        - Real; Actual pickup time.
        - Earliest; Expected earliest pick-up time. Unclear how it is determined.
        - Latest; Expected latest pick-up time. Unclear how the interval with the earliest departure time is determined.
    - Arrival time; Date and time of the drop off of the passenger(s).
        - Real; Actual drop off time.
        - Earliest; Expected earliest drop off time. A sum of the earliest departure time and the expected trip time.
        - Latest; Same interval with the earliest arrival times as the earliest and latest departure times.
    - Departure location; Latitude and Longitude of the pickup location.
    - Arrival location; Latitude and longitude of the drop off location.
    - Kilometers; Length of the trip if no detours to pick up others has to be made.
    - In-vehicle time; The duration of the trip in seconds.

Separately a database is available to find the ID's and the names of the stops based on the latitudes and longitudes of the departure and arrival locations. Based on the distances between the stops and each location, the corresponding stops are determined.

2.1.3) Limitations dataset

The dataset contained 9222 records of which 8978, with the trip status customer arrived, are used in this thesis. The other records could not be used because some only had payment information (88 records), others had no departure and arrival time, either they were cancelled by the driver (156 records) or the client (15 records), or the trip status was marked as "refunded" (61 records). Something that should be taken into consideration is that the data regarding the records of the subcontractors is

missing. According to Breng Flex, about 15,000 rides have been provided, but this dataset contains roughly only 60 percent of that.

It is unclear how some data has been determined. For example, the earliest and latest (departure and arrival) times; the expectation would be that the earliest departure time should be later than the booking time. This is not the case for 568 records, with times ranging from 11 seconds to 7 minutes (e.g. trip ID 216325 where the earliest departure time is 26 seconds earlier than the booking time). However the intervals between the earliest and latest times are always the same for departures and arrivals. So it can be reliably used to calculate expected in-vehicle times using the earliest or latest departure and arrival times.

Some derived values in the data set were found to be slightly imprecise. For example the in-vehicle times are also given in rounded minutes, but the way of rounding is sometimes unclear (695 seconds turn into 11 minutes, but is actually 11 minutes and 35 seconds). To prevent the usage of these somewhat less precise values, the most basic information is used to again derive the proper values (so for the in-vehicle time, the real arrival time minus the real departure time is used). Also, after doing some calculations, 77 trips had an average speed of over 120 kilometers per hour, with 46 trips even exceeding 1,000 kilometers per hour. The most extreme example is trip ID 131074 with an average speed of 10748 km/h, with a distance of 11.9 kilometers between the two stops and an in-vehicle time of 4 seconds. A better understanding of how the data was recorded would help understand how these outliers were recorded. Since the source of this anomalies is unknown, and to display the whole data, these records were also used for this analysis.

2.2) Breng Flex performance and usage

The first sub question is:

a) How are the performance and the usage of the urban DRT system of Breng Flex? How has the usage temporally evolved?

For the spatial analysis ArcGis is used to draw the stops on a map for Arnhem and Nijmegen. Also the usage of the stops as departure or arrival location is visualized in ArcGis. Using Gephi, the network flow is visualized using the GeoLayout with a Mercator projection, visualizing the usage of the stops and the usage of the different connection between stops.

2.3) First/last mile

The second sub question is:

b) How often has Breng Flex been used as a first/last mile to/from the train stations?

Firstly the stops near train stations are identified. Then the trips from or to stops near train stations are identified.

2.4) Comparison with regular public transportation alternatives

The third sub question is:

c) What are the perceived and real difference in times when using Breng Flex in comparison to existing public transportation options?

The data for the alternatives by public transport were obtained using the Google Directions API. This was done by using Breng Flex's reservation time, day of the week, whether the public transport follows a holiday schedule, origin coordinates and destination coordinates. The date of the ride is checked for whether the public transport follows a holiday schedule, because the API does not allow for planning

on time in the past. The dates used in the request for the API are from July 2nd 2017 to July 16th 2017. The second week is used for the alternatives during the holiday schedule. Different alternatives were returned and the alternative with the earliest arrival time is chosen. The alternative contained the values of distance, duration, waiting time before and during transfers, in-vehicle time, number of transfers and the transit mode. To automate the calls for this API Matlab is used. The data obtained is than analyzed in Excel. The perceived journey times are calculated using the factors provided in Table 1. The waiting time for Breng Flex is assumed expected, because the app will give the expected pickup time. The transfers are assumed to be to on-street buses.

Table 1 Perceived time - walk, wait, in-vehicle and transfer times - recommended (default) values (19)

Attribute	Value(1)	Notes
In-vehicle time- standing	2.0*V	Valid for 'normal' standing conditions (exclude crush conditions)
Walk time	2.0*V	
Wait time- expected	2.0*V	Needs an associated wait time v headway relationship for modelling purposes
- unexpected	5.0*V	Needs means of estimating delays and effect on waiting time.
Transfer - to on-street bus	10 mins*V	Apply in addition to all elapsed time.
- to other modes	8 mins*V	

Note: (1) All values relative to standard value (V) for seated bus passengers.

3) Analysis

The analyses are performed to answer the three sub questions. Firstly, the analysis is done for the performance and usage of Breng Flex, secondly for the use of References to the region Arnhem-Velp-Rozendaal and Nijmegen-'Berg en Dal'-Oosterhout-Wijchen will be referred to as Arnhem and Nijmegen.

3.1) Breng Flex performance and usage

The analysis is done for:

a) How is the performance and the usage of the urban DRT system Breng Flex? How has the usage temporally evolved?

The analysis of the Breng Flex performance and usage is analyzed in three parts. Firstly, the spatial analysis shows where Breng Flex is used and what stops are more often used. Secondly, the demand analysis shows how the demand has evolved in time and changes during each weekday. Lastly, the analysis of the rides shows how the individual rides are changing in time.

3.1.1) Spatial

Firstly the distribution of the stops of both cities are compared. Then the each city will be analyzed in terms of usage of the stops for departures and arrivals.

In Arnhem, 258 stops are available (Figure 2), of which 6 stops are located nearby a train station (represented in the map as a white dot with a blue edge instead of as a purple dot). At the central station of Arnhem, two stops are available, one at the front and one at the back of the station. In Nijmegen, 255 stops are available (Figure 3) of which also 6 lie nearby a train station (represented in the map as a white dot with a blue edge instead of as a purple dot), but all train stations have exclusively one stop here. In both cities, the stops are evenly spread around the area with a few stops further away in the outer areas.

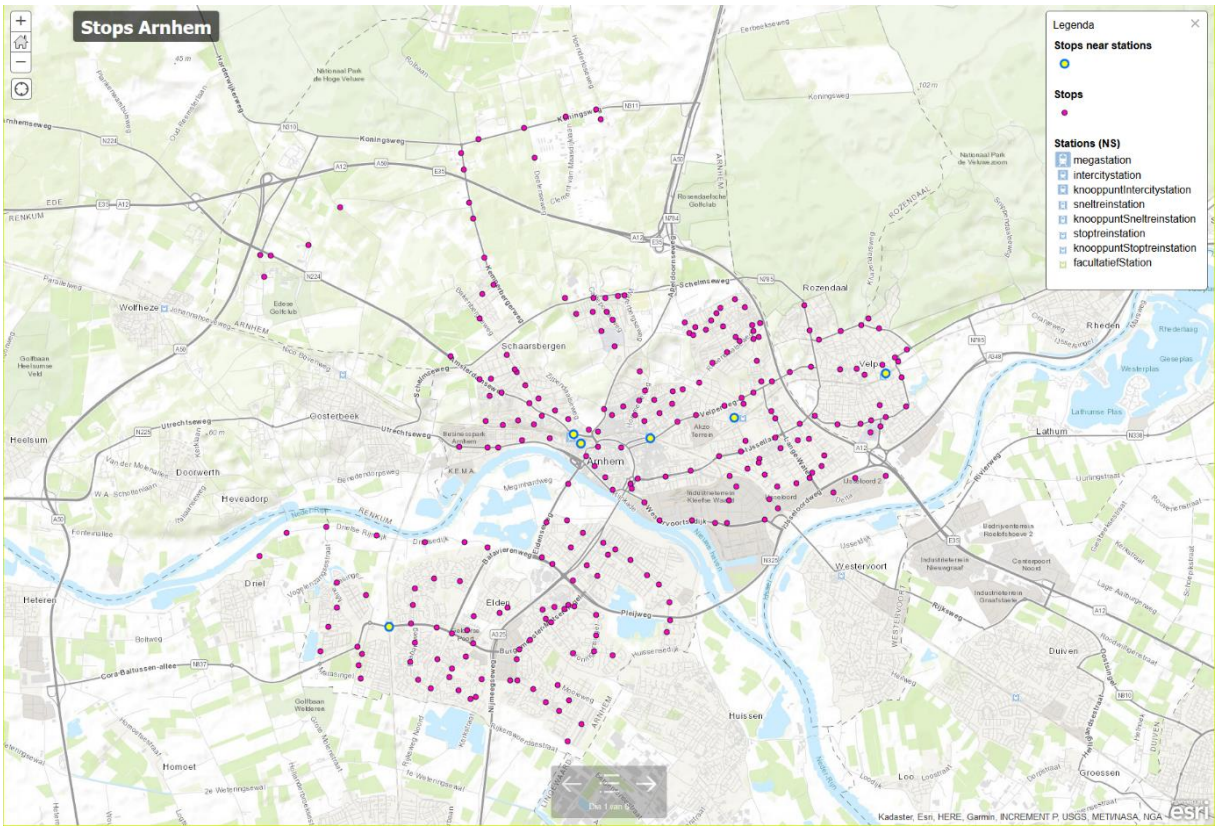

Figure 2 Stops in Arnhem

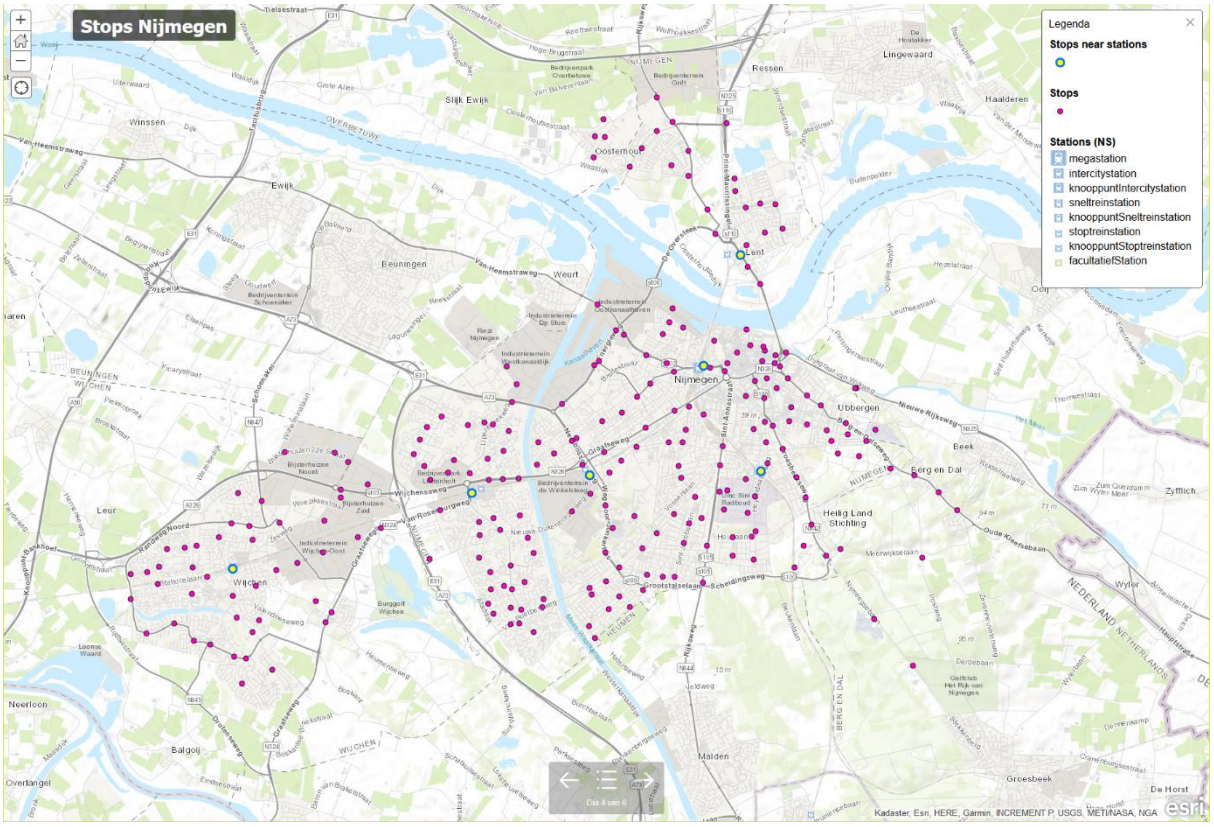

Figure 3 Stops in Nijmegen

The usage of the stops for departures and arrivals of Arnhem is visualized in Figure 4 and Figure 5. The small red dots are stops that have not been used for departures or arrivals. The other stops are visualized as blue dots for departures and green dots for arrivals. The more darker and larger these dots are, the more often they have been used. Two scales are used to get a better feeling of the data. It can be noted that the departures and arrivals figures look quite similar, so the stops that are used often as departure stop are also often used as arrival stop. Most of the stops have been used only a small amount of stops has not been used as a departure stop (25 stops) and even a smaller amount of stops has not been used as a arrival stop (22 stops).

The most used stops for departures are “Centraal Station Arnhem” (186 departures), “Willemsplein, Arnhem” (182 departures) and “Onder de Linden, Arnhem” (135 departures). Also interesting is the large dark dot further away from the city center in the north-west corner. This is the fifth most used stop in number of departures, “Camping/Manege De Maesberg, Arnhem” (100 departures). The most used stops for arrivals are “Willemsplein, Arnhem” (220 arrivals), “Centraal Station Arnhem” (209 arrivals) and “Onder de Linden, Arnhem” (122 arrivals). Interesting to mention is the large usage of the stop that leads to the hospital “Ziekenhuis Rijnstate, Arnhem” (77 arrivals), which shows that Breng Flex is a service that fulfils the needs of medical trips.

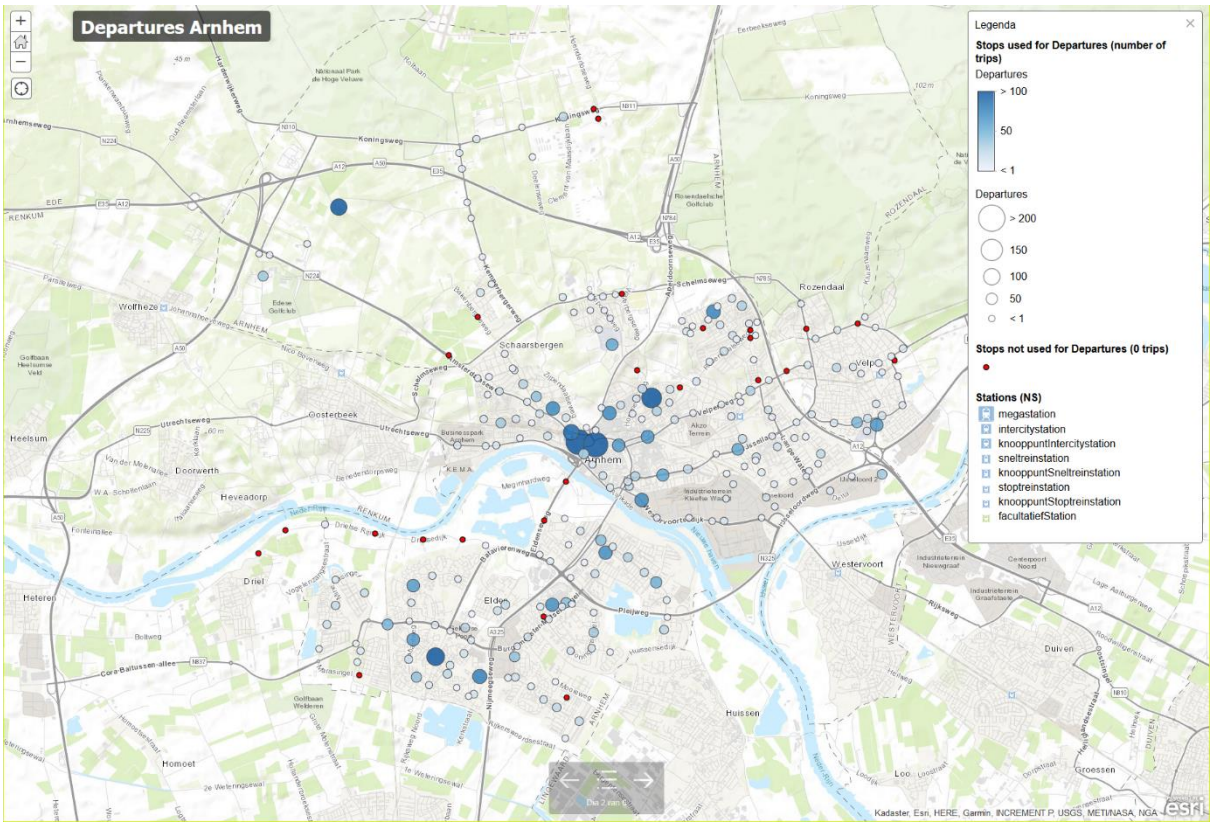

Figure 4 Stops usage for departures Arnhem

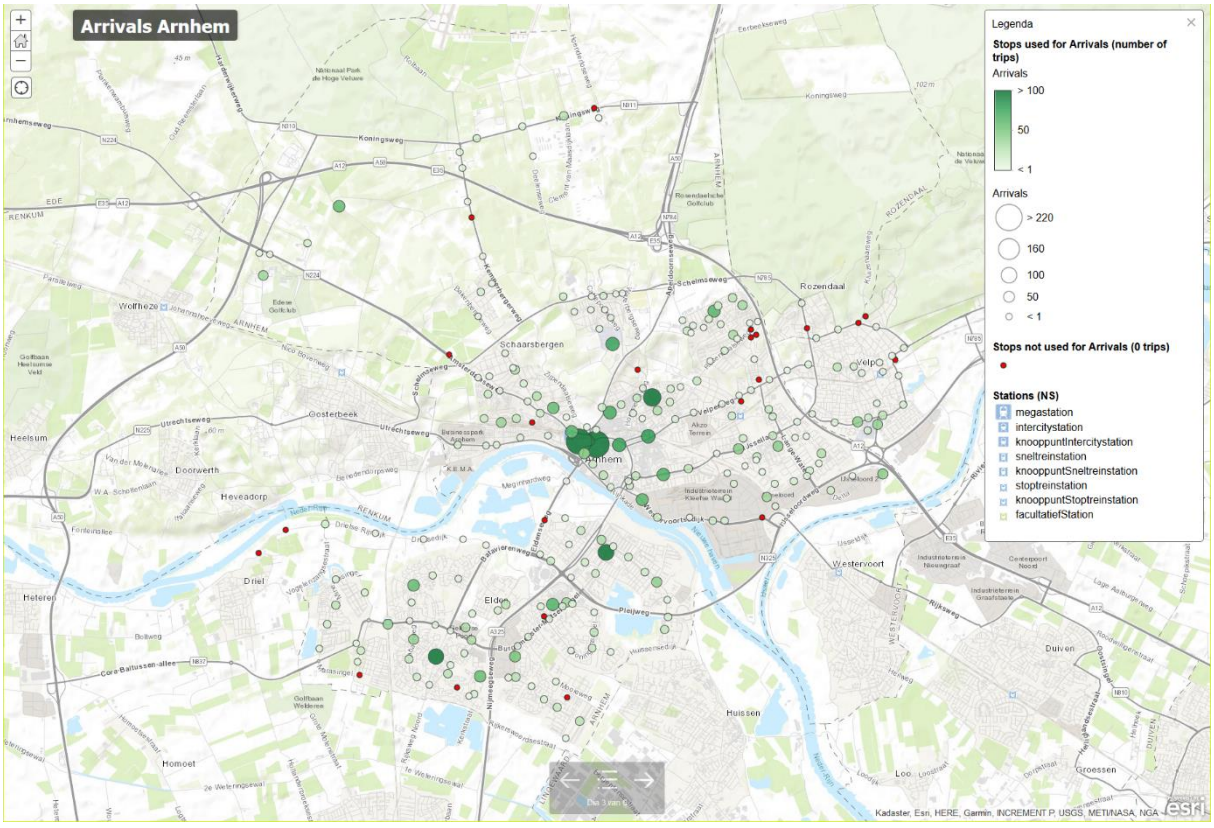

Figure 5 Stops usage for arrivals Arnhem

The usage of the stops for departures and arrivals of Nijmegen is visualized in Figure 6 and Figure 7. The small red dots are stops that have not been used for departures or arrivals. The other stops are visualized as blue dots for departures and green dots for arrivals. The darker and larger these are, the more often they have been used. Two scales are used to get a better feeling of the data. The departures and arrivals' figures look quite similar to each other, i.e. the stops that are often used as departure stop are also often used as arrival stop. Most of the stops have been used and only a small amount of stops has not yet been used as a departure stop (17 stops) and even a smaller amount of stops has not yet been used as a arrival stop (10 stops).

The most used stops for departures are "Centraal Station, Nijmegen" (295 departures), "Station Dukenburg, Nijmegen" (202 departures) and "Plein 1944, Nijmegen" (172 departures). An interesting fourth most used stop is "OBG, Nijmegen" (130 departures). This is the stop near OBG, who offers home-based care, nursing services and also hosts a variety of well-being activities for the elderly. The most used stops for arrivals are "Plein 1944, Nijmegen" (186 arrivals), "Centraal Station, Nijmegen" (185 arrivals) and "Bijsterhuizen 21, Wijchen" (127 arrivals). Again, the fourth most used is "OBG, Nijmegen" (109 arrivals).

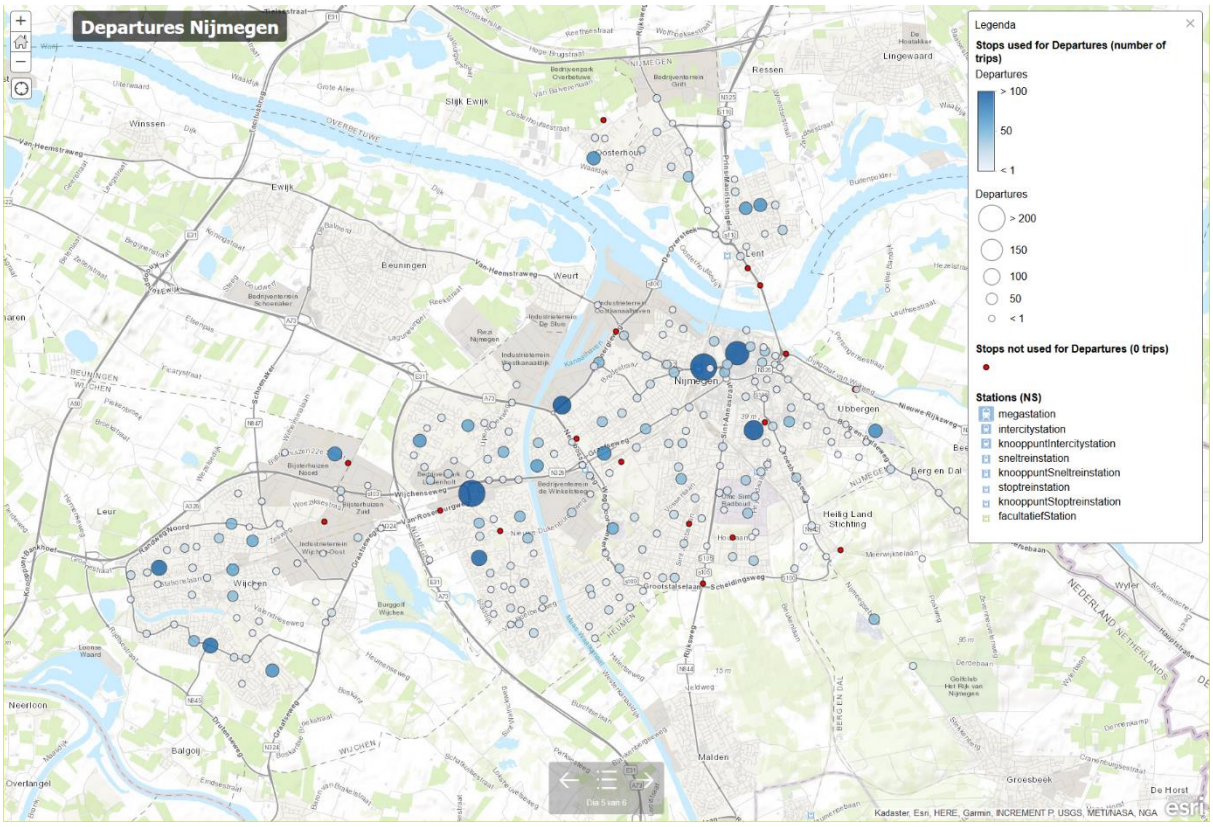

Figure 6 Stops usage for departures Nijmegen

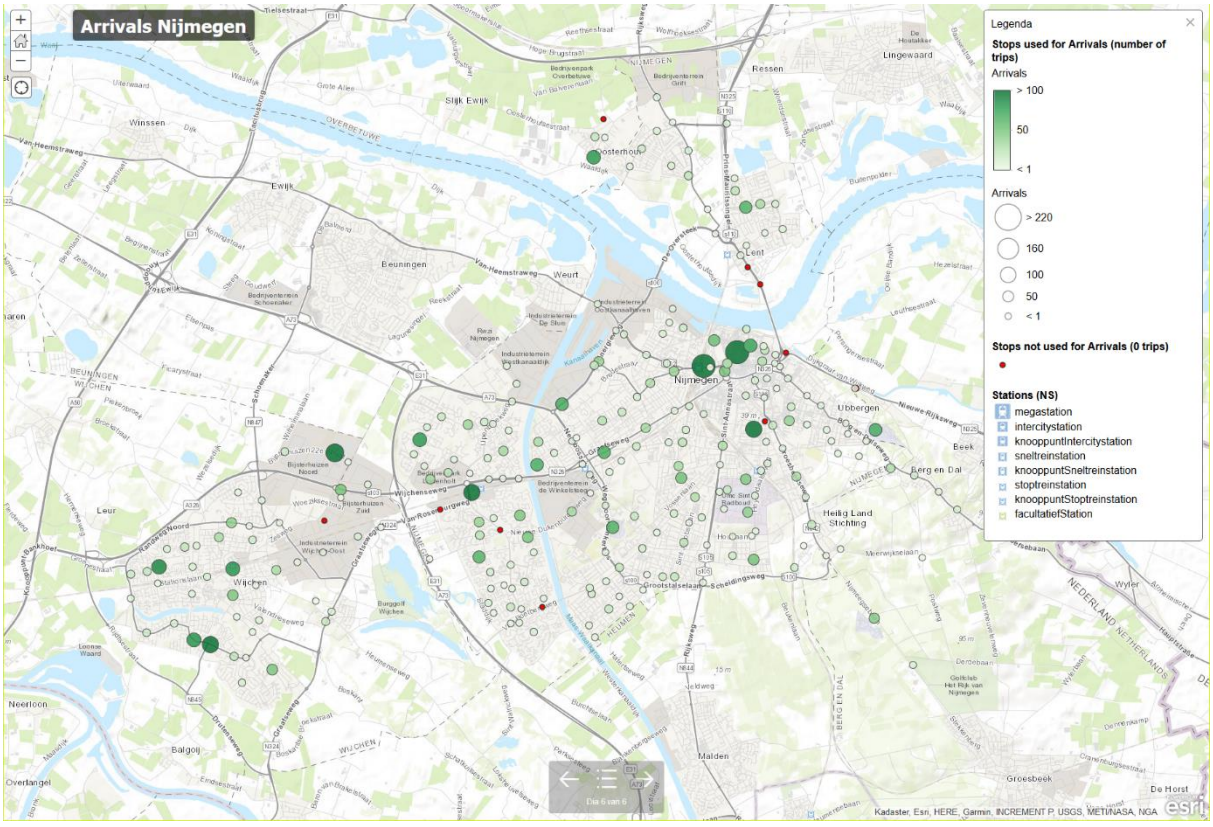

Figure 7 Stops usage for arrivals Nijmegen

For both Arnhem (Figure 8) and Nijmegen (Figure 9), the network flow is visualized. These figures give an impression of the spatial usage of Breng Flex. In the appendices higher resolution figures are available. All stops are projected at their geographic location using the Mercator projection. The size and color of the nodes, which are the stops, give an impression of how often the nodes have been used as a stop (departures and arrivals combined). If stops are less used, they are visualized smaller and in a darker pink color. If stops are more often used, they are drawn larger and greener. The small red dots are stops that have never been used. The lines, which represent the connections between stops, are also following this size and color scheme. So, less rides means thinner lines with a stronger pink tone and more rides means thicker and greener lines. The direction of the rides is also visible in the figures. The directions of the rides are drawn clockwise. The color and the size or thickness of the elements are not linear but chosen with a spline function. The spline made a more informative drawing. The first few rides add more to the size of stops than the latter rides. The same with the colors, at 1 ride they are thin and very pink. After maybe 10 rides they start to turn green and quite thick. After that they slowly turn greener and thicker. So a line double the width of another line does not mean twice more rides.

In Arnhem (Figure 8), the network flow shows that a lot of different connections are made, the pink cloud shows that. Breng Flex is more used at the stops in the center, but also the stops in the outer areas have a lot of rides. Those connections are made less often. There are also some thick green connections. Some go from one side of the area to the other side. For example, a green line goes from “Sportcentrum Papendaal, Arnhem” to “Haverland, Velp”, at the other side of the area. Analyzing in detail the rides of some of the most often used connections, it can be seen that for some routes, it is just a few passengers who often take that connection. At the stop “Camping/Manege De Maesberg, Arnhem” this phenomena is clearly visible.

In Nijmegen (Figure 9), the network flow shows that a lot of different connections are made. The pink cloud is the most present in Nijmegen, in the middle of the figure. Breng Flex is also used very often to go to Wijchen, in the west. Most of the rides from or to Wijchen are departing or arriving at Nijmegen. An interesting often used connection is the connection between “Van Woerkomstraat, Oosterhout” and “Sint Maartenskliniek, Nijmegen”. It is likely that a few persons are making this connection regularly. Another interesting stop is “Vijverhof, Nijmegen” because it is a quite frequently used stop, but the edges aren’t very thick. That means that people come from and go to a lot of different stops.

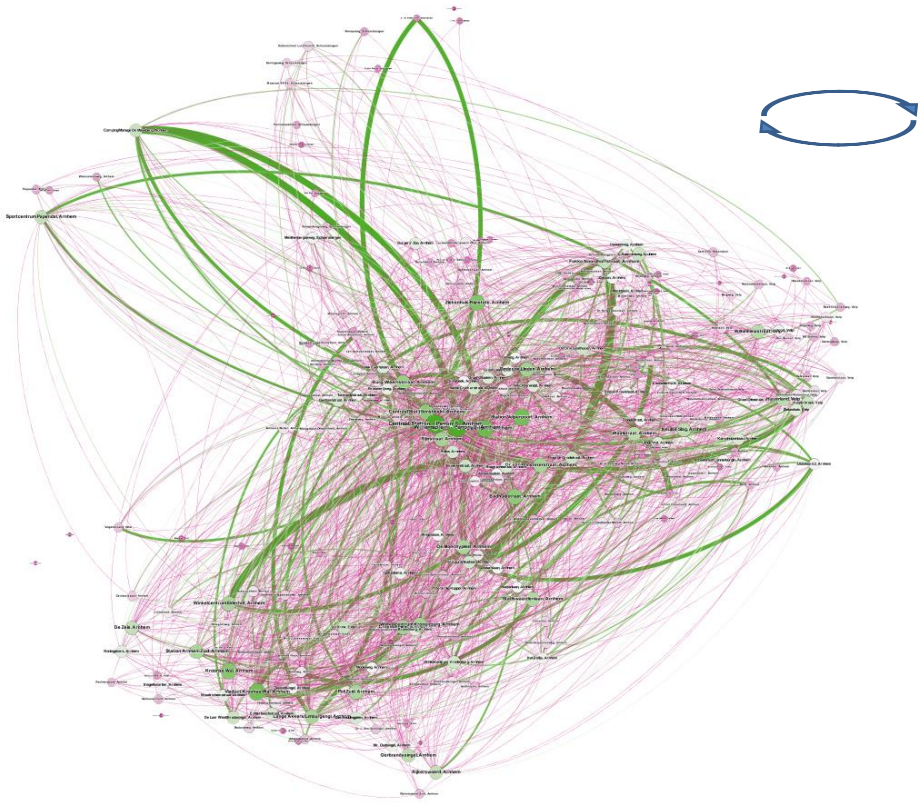

Figure 8 Network flow visualization for Arnhem (greener and larger/thicker means more used)

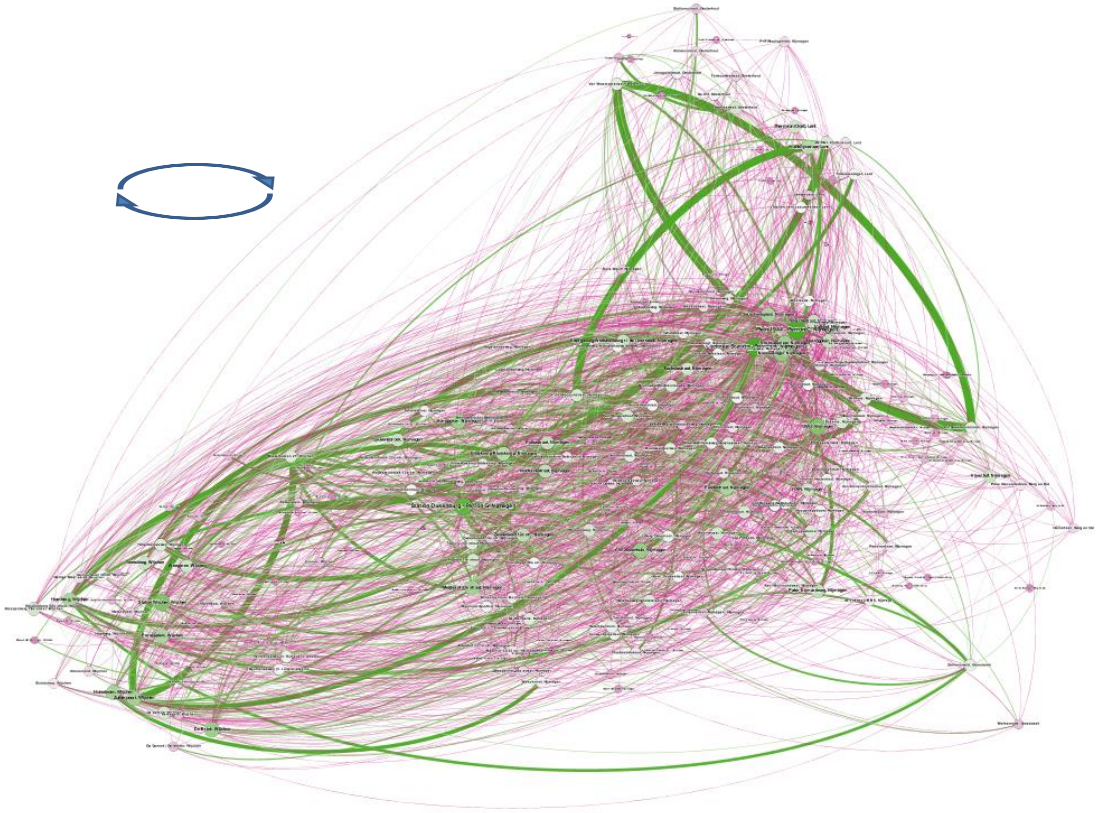

Figure 9 Network flow visualization for Nijmegen (greener and larger/thicker means more used)

3.1.2) Demand

The demand of Breng Flex is evaluated. Firstly, the demand is calculated per month. Secondly, the demand per day of the week is calculated per hour.

The following figures show the number of rides (Figure 10), distances (Figure 11 (left)) and in-vehicle times (Figure 11 (right)) per day. These figures have been expressed as the average amount per day and not the total per month to account for the different number of days in the different months. A small remark is that the data starts at December 15th 2016 and ends at May 18th 2017. Because the number of rides is still increasing, the figures are pessimistic about the numbers in May. All these figures show an increasing usage of Breng Flex. The end of this growth is not visible yet. The number of rides are almost the same for Arnhem and Nijmegen. The distances and the in-vehicle times show a larger difference and are larger for Nijmegen than for Arnhem. This means that rides in Nijmegen are longer and have a longer duration on average.

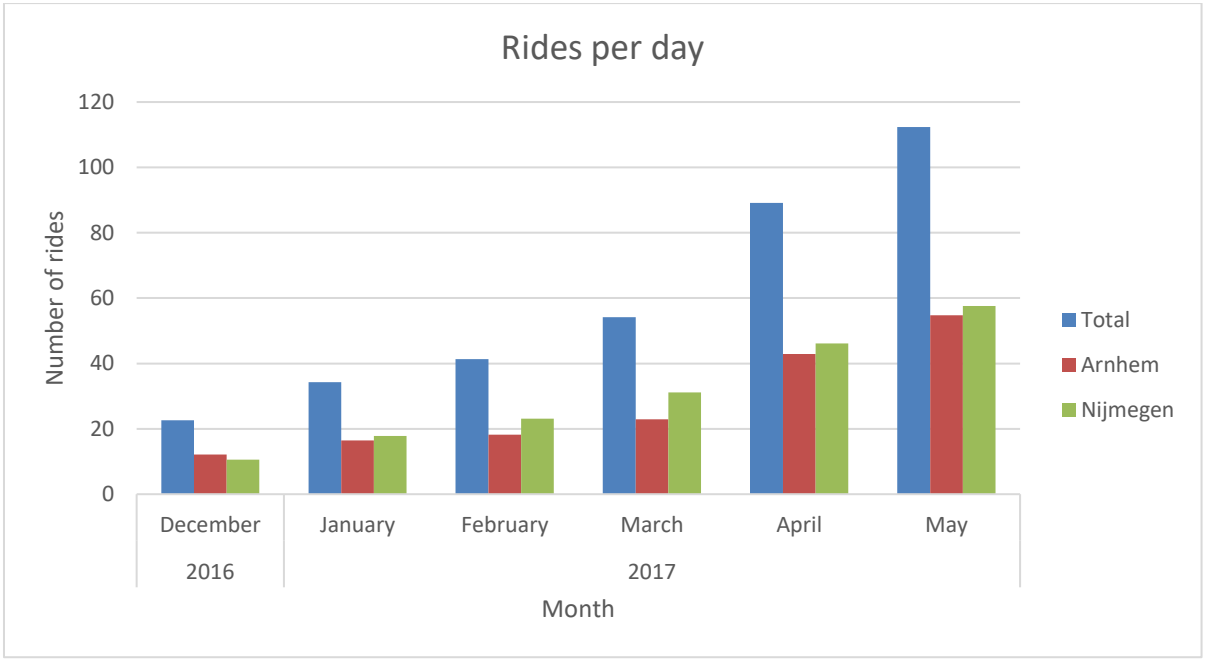

Figure 10 Average number of rides each day per month

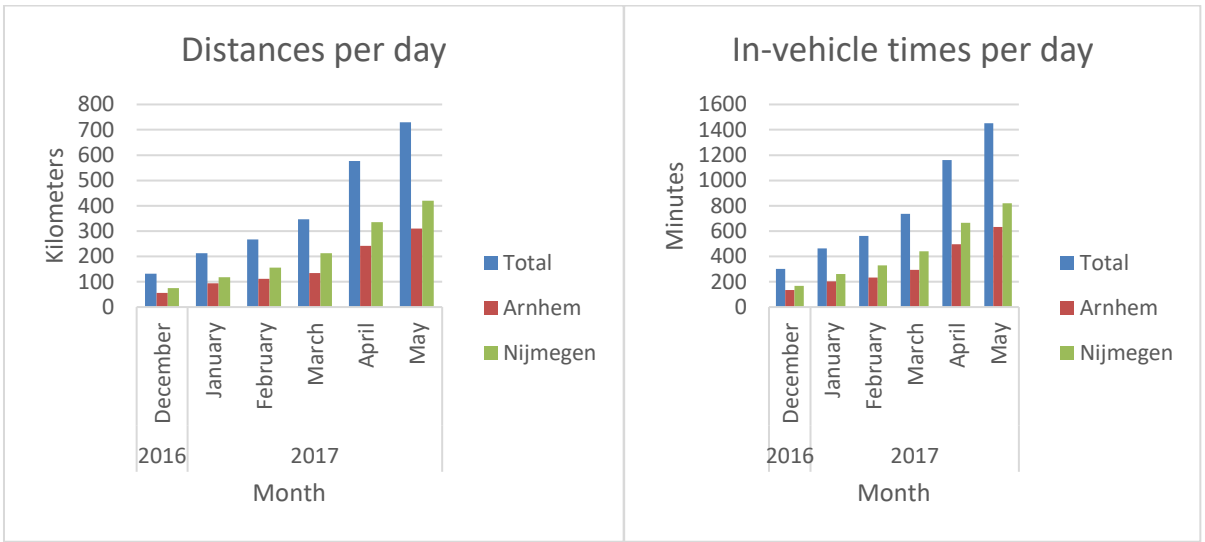

Figure 11 Average distances (left) and in-vehicle times (right) each day per month

To further analyze the demand, the composition of the passengers is divided into passengers who use Breng Flex for the first time, the second time and the third or more times. A small remark, the composition of May has been forecasted for the dates not available in the data (from 19th May onwards). The prognosis of May is done by counting the number of rides in the first 18 days and are multiplied by 31/18. So the real number of rides would probably become higher because there the usage of Breng Flex is still increasing. This is done in three figures, the first figure for both areas combined (Figure 12 (left)), the second figure for Arnhem (Figure 12 (middle)) and the third figure for Nijmegen (Figure 12 (right)).

The shape of all three figures looks like each other. The parts of the first timers and the second timers are almost the same per month. In other words, most of the people will use Breng Flex at least twice in the same month. This is explained by the fact that most people tend to go out and come back home. Also a month is quite long so people might use Breng Flex for the second time after a few weeks and it still counts in the same month. The number of rides are rising at a similar rate and the absolute number of rides of the regular user rises the fastest. So Breng Flex is an attractive travel mode to keep using regularly.

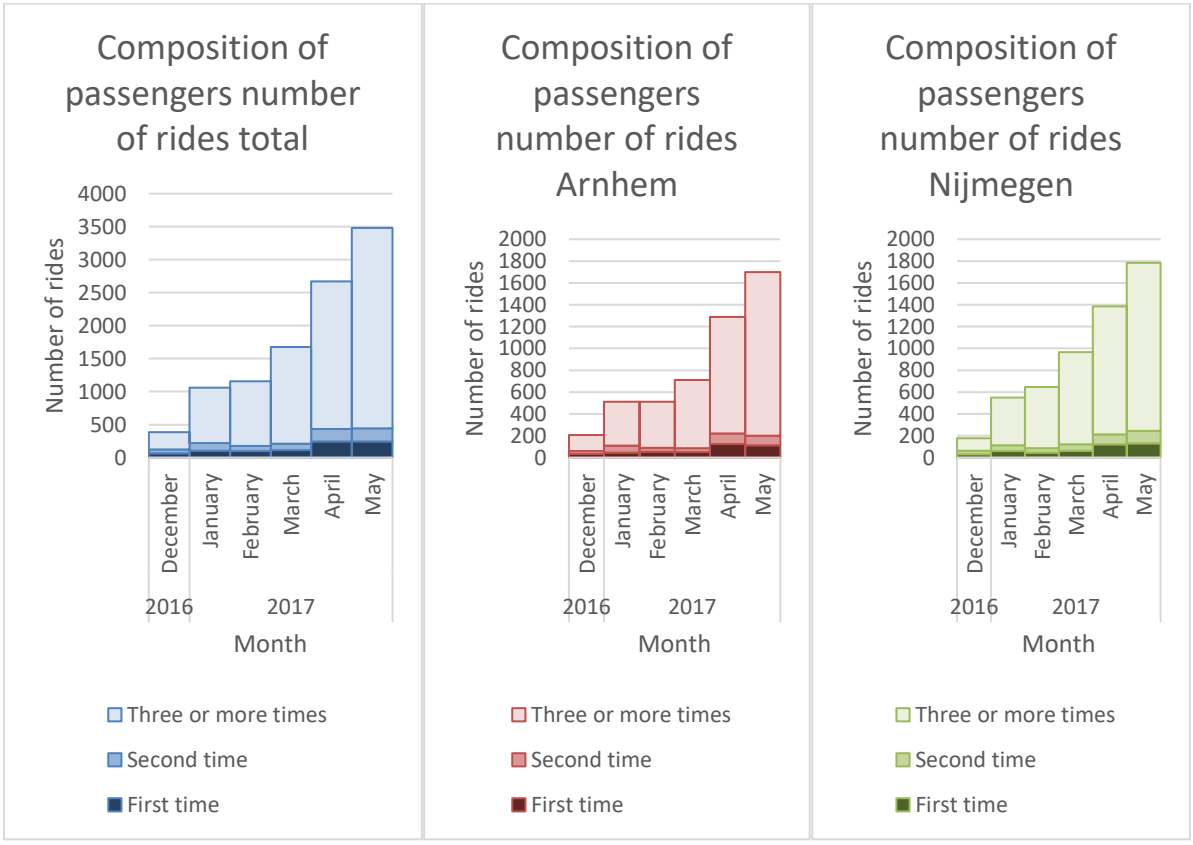

Figure 12 Composition of passengers in number of times user of Breng Flex per month, for both regions (left), for Arnhem (middle) and for Nijmegen (right)

All the data is combined and analyzed to calculate the demand during each weekday. The total number of rides per hour are the sum of the number of rides in a certain hour on a weekday. The total demand per hour is shown for both regions combined (Figure 13) The summation is done for the rides between half an hour before and half an hour after the mentioned time. The data points in the figures are at the hours and also at half an hours. For example the total demand per hour of 09:30 of Wednesday is calculated by counting all the rides booked on Wednesday between 09:00 and 10:00. In the appendices

are figures included where each figure shows the demand per weekday for both regions, only Arnhem and only Nijmegen.

For example for the combination of both regions, 7 o'clock in the morning on Wednesdays has a total demand of 108 rides. The total number of each weekday is 22, because the data set contains data of 22 weeks. So the average demand per hour on a Wednesday between 06:30 to 07:30 is 108 divided by 22 is 4.9 rides. However the figures use the total number of rides instead of the average number of rides because Breng Flex is growing. So the average is not an accurate representation of the current state of Breng Flex.

The demand in Arnhem and Nijmegen during the day stays quite similar. The demand grows rapidly after 04:30 on workdays with a peak at 06:30. These might be commuters who have start early on the job and missing an proper public transport alternative. On Saturdays and Sundays Breng Flex starts later than on weekdays as is visible from the zero demand before a certain time. The demand decreases rapidly after 22:00 on most days. On Fridays and Saturdays the demand decreases later.

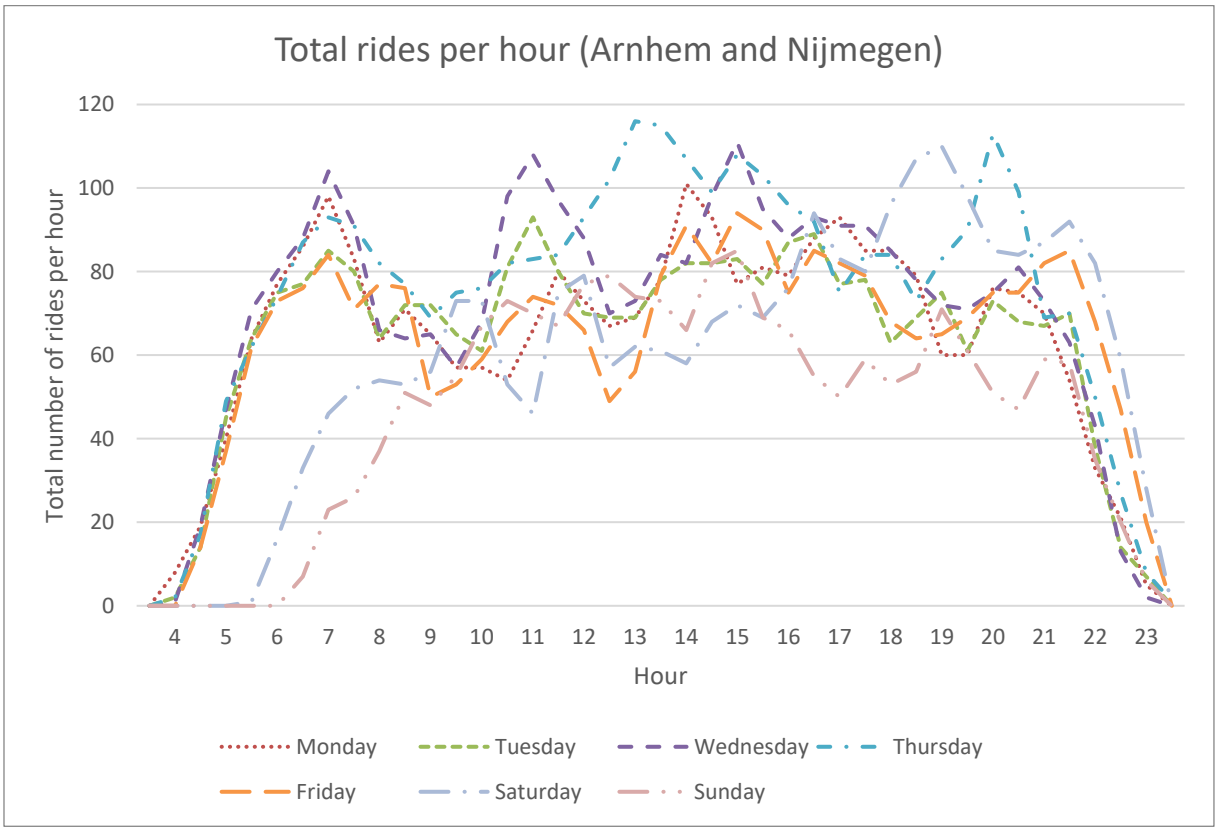

Figure 13 Demand per hour for both regions (total number of rides of the first 5 months)

3.1.3) Rides

The rides are analyzed in two parts, firstly the temporal change and secondly the statistical analysis of all the rides.

Temporal

The temporal analysis is done using three indicators. Firstly the average distance per ride, secondly the average in-vehicle time per ride and lastly the average waiting time per ride, and each of this indicators is expressed for each month.

The average distance per ride is visualized in Figure 14 (left). The distances per region fluctuate only slightly. The average distances for all (Total) trips in May is 6.5 km and remained stable after a little

growth in January and February. Visible in the figure is the longer average distances per ride in Nijmegen (7.3 km in May) in comparison to Arnhem (5.7 km in May). The area of operation of Breng Flex is larger in Nijmegen.

The evolution of the average in-vehicle time per trip is visualized in Figure 14 (right). The duration of the rides remained equal between April and May. The average in-vehicle time for all (Total) trips in May is 12.9 minutes and has only decreased since the beginning. The average in-vehicle times (Figure 14 (right)) has the same characteristics as the average distance per ride (Figure 14 (left)), so that Nijmegen (14.3 minutes in May) has rides with a longer duration in comparison to Arnhem (11.5 minutes in May). meaning the average speed of the vehicles does not differs much.

The average waiting time is visualized in Figure 15. The values are fluctuating around a little bit between 9 and 10 minutes. These have not changed much after starting the pilot. This means that even with the large increase in number of rides the capacity of Breng Flex is still sufficient.

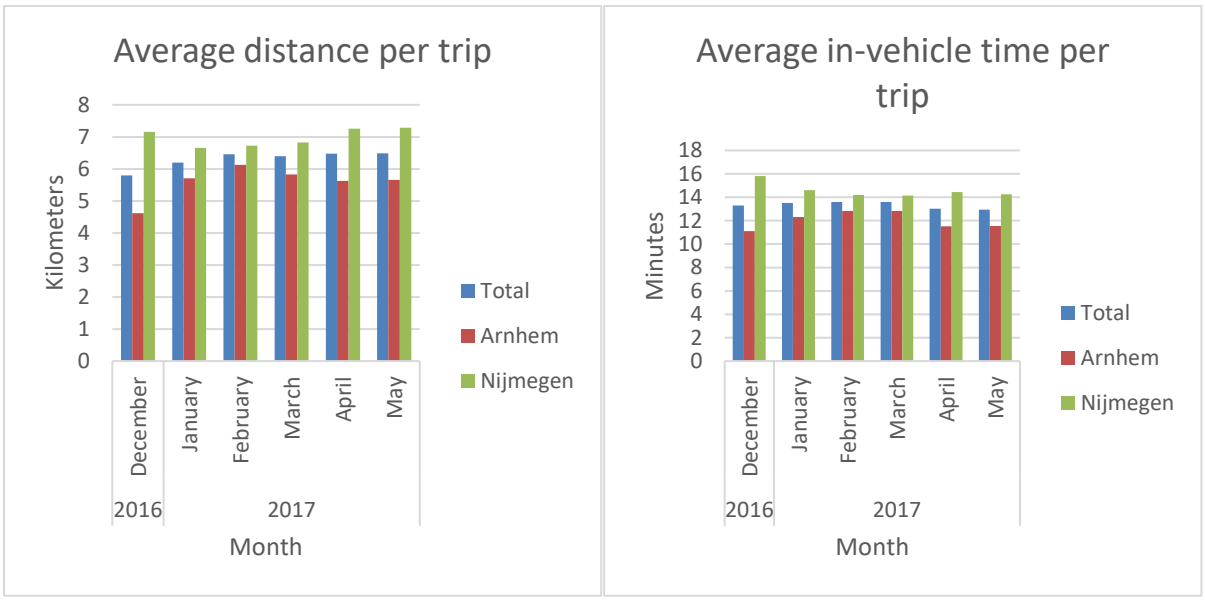

Figure 14 Average kilometers (left) and in-vehicle time (right) per ride per month

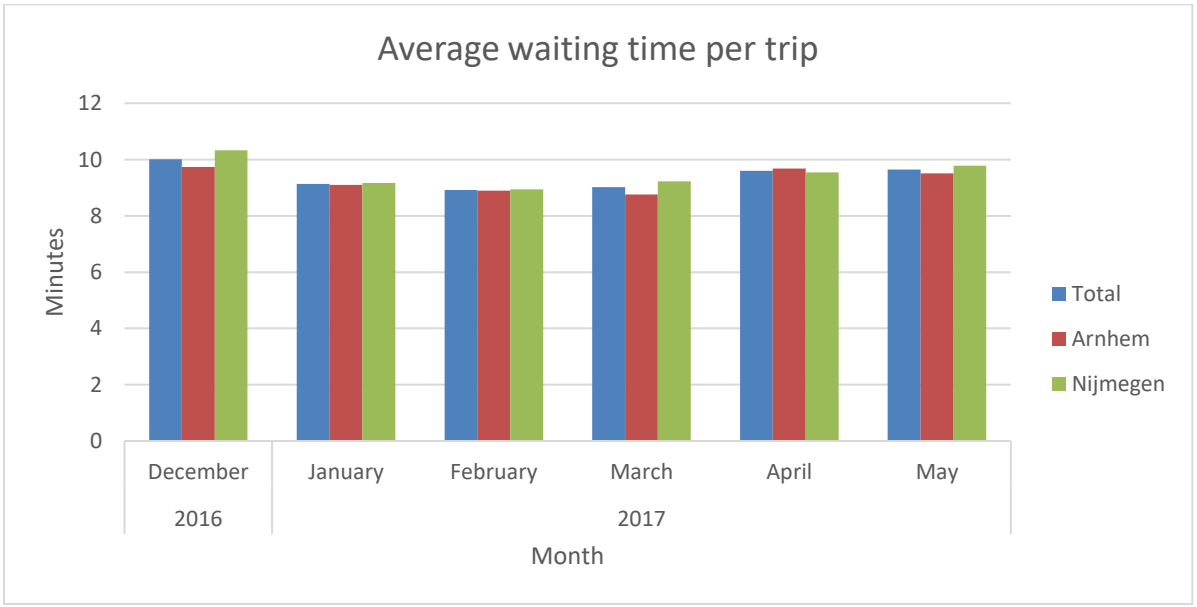

Figure 15 Average waiting time per ride per month

Statistical

The statistical analysis is done for the waiting times, real and expected in-vehicle times, delay or longer duration of the real in comparison to the expected in-vehicle times, distances and the average speed each ride. Firstly the table with the descriptive statistics for all the rides is given (Table 2), containing the mean, median, standard deviation, minimum value, maximum value and the sample size. The 10th, 25th, 50th, 75th and 90th percentile values are also calculated. In the second part the histograms can be found and are analyzed and discussed.

The total sample size is 8978 for each histogram, of which 4213 are for Arnhem and 4765 are for Nijmegen. Some minimum and maximum values are unrealistic like the delayed times and the average speeds, in these cases using the percentile values instead of the means is more representative. The most interesting values in the table is that for only 10 % of the rides the waiting time exceeds 15 minutes and for 75 % of the rides the waiting time stays under 12 minutes. The delay of Breng Flex is in 90 % less than 5 minutes. The average speed of the rides is mostly between 20 and 40 km/h.

Table 2 Breng Flex Descriptive Statistics total

Breng Flex	Waiting Time [Minute]	Experienced In-vehicle Time [Minute]	Expected In-vehicle Time [Minute]	Difference between experienced and expected In-vehicle Time [Minute]	Distance [km]	Average speed [km/h]
Mean	9.38	13.26	12.01	1.24	6.40	44.68
Median	8.67	12.60	11.57	0.88	6.08	28.90
Standard Deviation	4.50	7.87	4.52	6.43	3.00	235.27
Minimum	0.50	0.05	1.13	-23.35	0.39	1.05
Maximum	65.32	545.55	28.22	531.73	17.55	10747.80
N	8978	8978	8978	8978	8978	8978
Percentile						
0.1	4.52	6.70	6.53	-1.77	2.80	19.35
0.25	6.30	9.30	8.65	-0.42	4.12	23.98
0.5	8.67	12.60	11.57	0.88	6.08	28.90
0.75	11.75	16.48	14.85	2.50	8.23	33.96
0.9	15.08	20.45	18.28	4.53	10.89	38.97

The distributions for the different parameters are analyzed for the area Arnhem, Nijmegen and for both combined. The distribution for the waiting times (Figure 16) shows that the more recurrent waiting times lie between 7 and 8 minutes. . The distributions for Arnhem and Nijmegen follow the same shape. The distribution of the in-vehicle times (Figure 17 (left)) shows that rides tend to last longer than 4 minutes.. The distribution for Nijmegen shows a wider distribution with a wider range of frequent values in comparison to Arnhem. The distribution of the expected in-vehicle times (Figure 17 (right)) shows a similar shape as the distribution of the in-vehicle times, but more narrow and with a more recurrent value. The distribution of the delays (Figure 18) has a high recurring of the values 0 and 1 minutes. Nijmegen has a larger share of rides experiences delays between -2 and 1 minutes in comparison to Arnhem. In only 8.1 % (728 rides) Breng Flex had a delay of 5 minutes or more.

The distribution of the distances (Figure 19 (left)) shows a remarkable decrease in frequencies at 8 kilometers, mainly caused by Nijmegen. This could mean that popular trips within Nijmegen are shorter than 8 kilometers and that intercity trips are longer than 8 kilometers.

The distribution of the average speed (Figure 19 (right)) shows a similar distribution for Arnhem and Nijmegen. Both have their more recurring value around 29 km/h. So longer rides in Nijmegen are not noticeable driven on faster ways. The peak at more than 60 km/h are mostly rides with an average speed of over 120 km/h, which could be ignored.

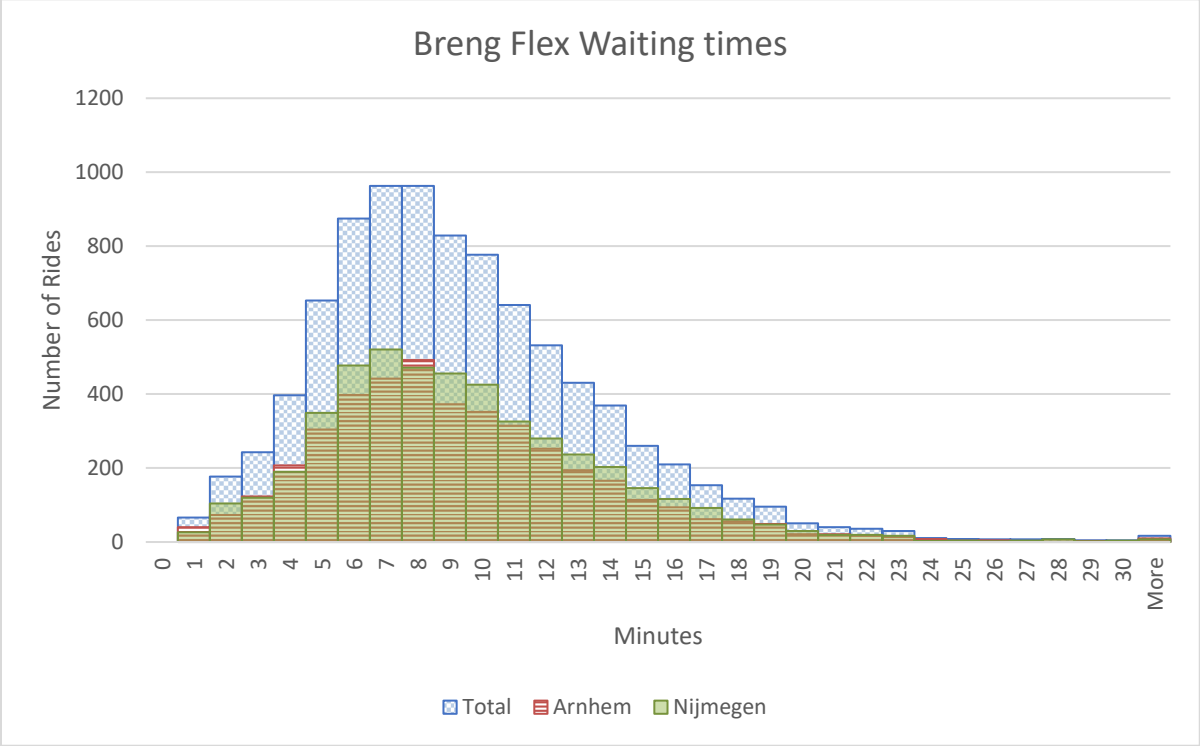

Figure 16 Breng Flex Distribution of waiting times (left) and in-vehicle times (right)

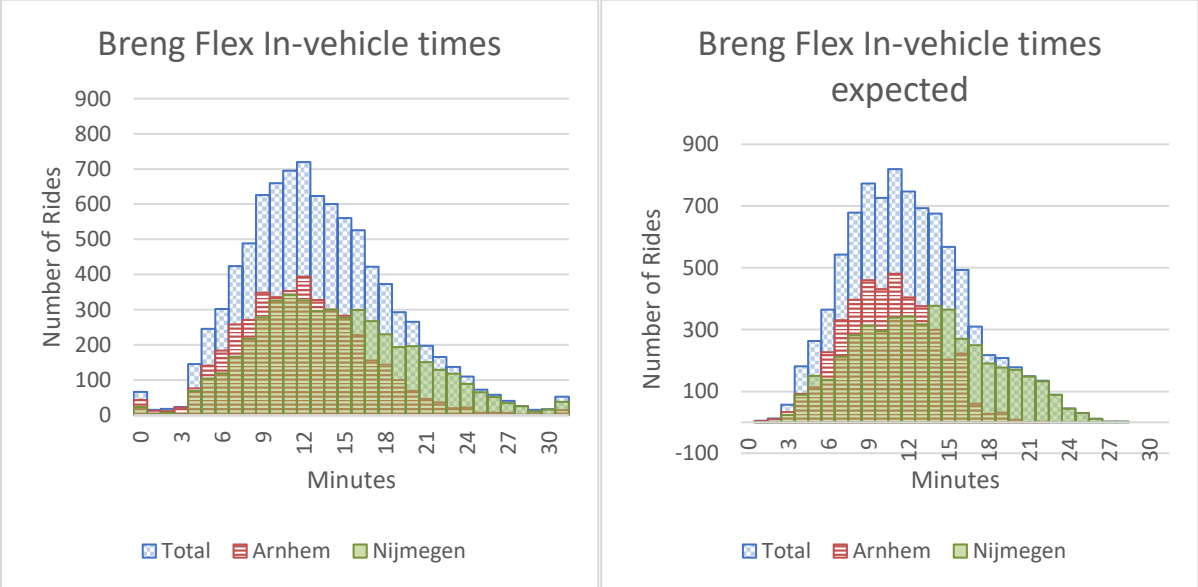

Figure 17 Breng Flex distribution of in-vehicle times experienced and expected (right)

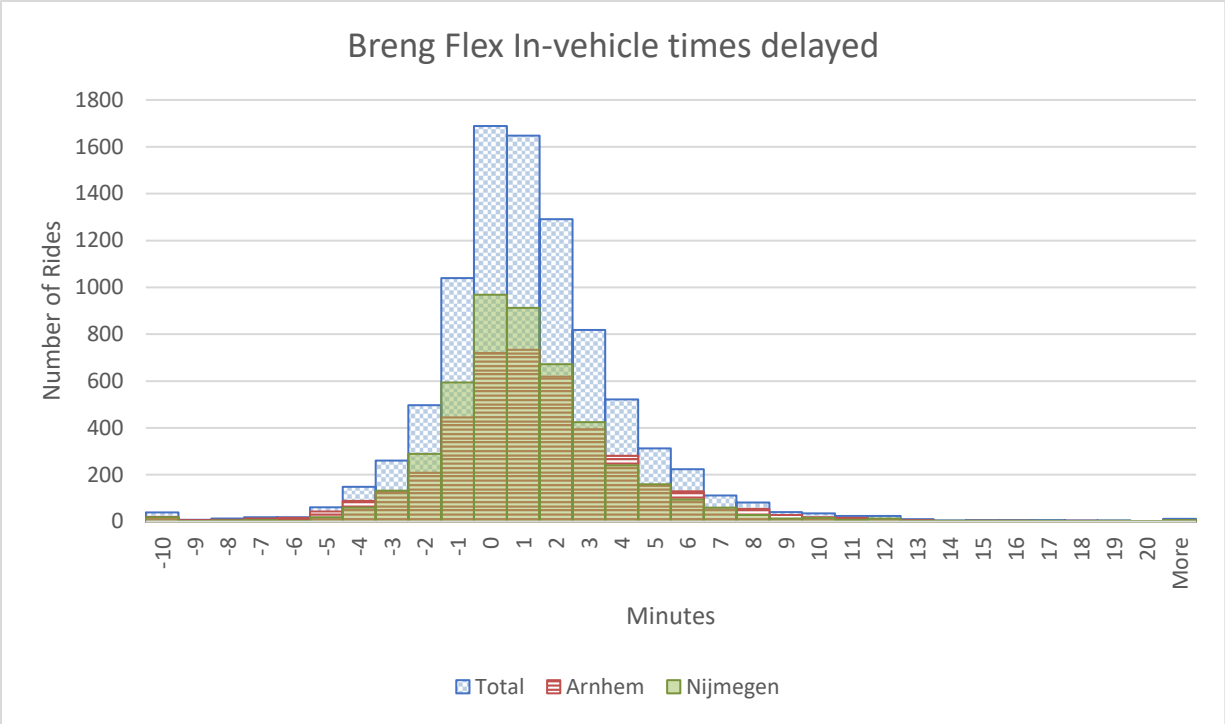

Figure 18 Breng Flex Distribution In-vehicle Times Delayed

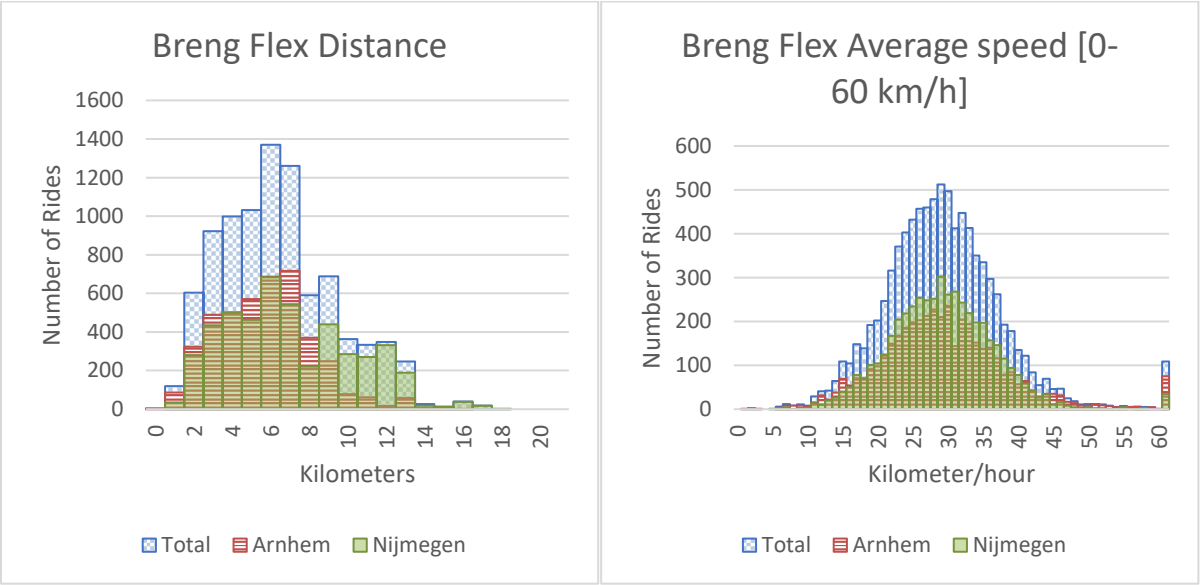

Figure 19 Breng Flex distribution of the distances (left) and the average speed [0-60 km/h] (right) of the rides

3.1.4) Summary

Spatial

Breng Flex has been used in the whole area. Almost all stops have been used, only 15 out of 258 stops in Arnhem and 8 out of 255 stops in Nijmegen have not been used during the evaluated period. Every train station in the areas is served by Breng Flex. The demand is high around the central train stations. Also worth mentioning is the frequent usage of Breng Flex at “Camping/Manege De Maesberg, Arnhem”, “Ziekenhuis Rijnstate, Arnhem” and “OBG, Nijmegen”. Breng Flex is used for regular leisure activities, for (regular) appointments at the doctor and by the elderly (paratransit). Some passengers regularly take the same rides. In both regions, a hotspot is visible in the center of the main cities. In Nijmegen Breng Flex is also often used between Nijmegen and Wijchen.

Demand

The demand is still growing and Breng Flex currently has a sufficient capacity to keep the average waiting time below 10 minutes. The total demand in number of rides has increased rapidly, in comparison to the previous month, with 31 % in March and 65 % in April. On Kingsday, April 26th, Breng Flex is used for 139 rides, the busiest day of Breng Flex so far. Every month, an increasing amount of people is trying out Breng Flex. Also increasing is the share of the rides by Breng Flex that are used by the regular customers. So Breng Flex has changed the preference of travel mode of passengers. In contrast to the high peaks during rush hours in the morning in other modes of transport, the demand of Breng Flex stays noticeable similar throughout the day.

Rides

The performance has remained steady, even with the increase in demand. Nijmegen has longer rides than Arnhem (on average), this results in longer rides in Nijmegen and thus similar average speeds. However, the average waiting time for Breng Flex is not longer in Nijmegen and was in the past months constant 9 to 10 minutes. The average distances also stayed constant in the past months. The in-vehicle time delays of Breng Flex are limited. Only 8.1 % of the rides with Breng Flex had a delay of 5 minutes or more, making Breng Flex a reliable alternative travel mode.

3.2) Breng Flex as first or last mile solution

The analysis is done for:

a) How often has Breng Flex been used as a first/last mile to/from the train stations?

3.2.1) Usage in combination with train stations

In Arnhem 6 stops are located nearby a train station. At the central station of Arnhem, two stops are available, one at the front (Centraal Station, Arnhem) and one at the back (Centraal Station (Sonsbeek), Arnhem) of the station. In Nijmegen also 6 stops are located nearby a train station, but all train stations have exclusively one stop here. In both cities, the stops are evenly spread around the area with a few stops further away in the outer areas. 19.7 % of the rides with Breng Flex departs or arrives at the stops near the train stations (Figure 20). 1765 rides start or end at stops nearby train stations. There are more departures (952 rides; 10.6 %) than arrivals (768 rides; 8.6 %) at train stations. Breng Flex is used 45 times with a train station as departure and arrival stop.

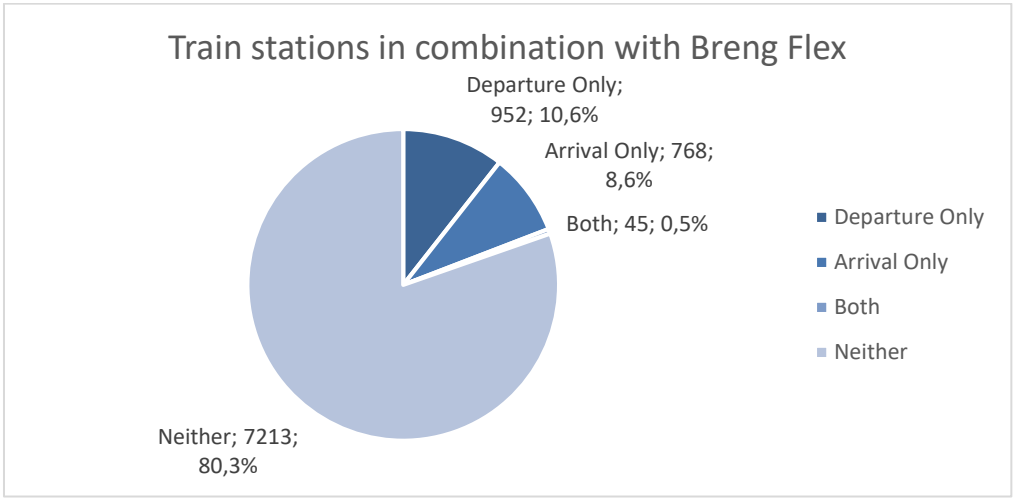

Figure 20 Train stations in combination with Breng Flex

3.2.2) Usage per stop near train station

A list of the stops near train stations is found in Table 3. Included in this table is the area Arnhem or Nijmegen, the number of rides using the stop as departure, arrival and in total. The train station "Centraal Station Arnhem" is used most for rides with Breng Flex (552 rides) followed by "Centraal Station Nijmegen" (480 rides). The stops (nearby train stations) in Arnhem have more arrivals than departures, namely 415 arrivals and 404 departures. In contrast to Arnhem, the stops in Nijmegen have more departures than arrivals, namely 593 departures and 398 arrivals.

Table 3 Breng Flex stops near train stations with number of rides, sorted on total rides

Breng Flex stops near train stations	Area	Departure	Arrival	Combined
Centraal Station, Nijmegen	Nijmegen	295	185	480
Centraal Station, Arnhem	Arnhem	186	209	395
Station Dukenburg, Nijmegen	Nijmegen	202	107	309
Centraal Station (Sonsbeek), Arnhem	Arnhem	92	65	157
Station Velperpoort, Arnhem	Arnhem	66	80	146
Station Wijchen, Wijchen	Nijmegen	55	83	138
Station Arnhem Zuid, Arnhem	Arnhem	46	39	85
Station Heyendaal, Nijmegen	Nijmegen	18	11	29
Station Presikhaaf, Arnhem	Arnhem	11	16	27
Station Lent Laauwikstraat, Lent	Nijmegen	14	7	21
Station Goffert, Nijmegen	Nijmegen	9	5	14
NS Station, Velp	Arnhem	3	6	9

3.2.3) Summary

Breng Flex may have been used as a first or last mile solution in combination with rail for up to 20 % of the rides. These rides start or end at a train station. More rides are departing from train stations (10.6 %) than arriving at train stations (8.6 %). 77.7 % of the departures are departing from the 3 most used train stations (CS Arnhem, CS Nijmegen, Dukenburg Nijmegen). For these stops with a lot of departures, a Breng Flex vehicle on standby at that location would be convenient for the passengers.

3.3) Comparison with regular public transportation alternatives

The analysis is done for:

b) What are the perceived and real difference in times when using Breng Flex in comparison to existing public transportation options?

The analysis of the journey durations is done separately for Arnhem and Nijmegen to see the influence of the differences of the areas and the significant different average distances of the rides. Firstly a general analysis is done for the obtained data. Secondly in the temporally analysis, the descriptive statistics and histograms are given for the waiting times before the travel and the real and perceived time gains (positive is time gain, negative is time loss) for the passengers of Breng Flex.

3.3.1) Data public transport

The data for the alternatives by public transport were obtained using the Google Directions API. This was done by using Breng Flex's reservation time, day of the week, whether the public transport follows a holiday schedule, origin coordinates and destination coordinates. Different alternatives were returned and the alternative with the earliest arrival time is chosen. The data obtained about the public transportation alternatives contains 4207 usable records (the API gave no alternatives for 5 rides) for Arnhem and 4765 records for Nijmegen.

Some of these alternatives only involved walking, 286 (7.3 %) alternatives in Arnhem and 248 (5.5 %) alternatives in Nijmegen. Some of these only walking alternatives were repeated regularly, e.g. a user of Breng Flex who has to be at work early. The duration of the walks take up to 60 minutes and can be found as the fastest alternative throughout the day. No convenient alternatives with public transportation were available for these rides. This can be due to the public transportation limitation like a low frequency bus schedule with the consequence of long waiting times, a high detour index (actual route distance divided by the direct straight line distance) for some routes or a booking time outside the operating hours. Another possibility for only walking as "best" public transportation alternative are short rides booked by passengers who use Breng Flex as paratransit, for whom walking is not an option. However, even with the only walking alternatives counted as 0 transfers, almost 40 % of the rides with Breng Flex saved passengers the trouble of at least one transfer in their journey (Figure 21).

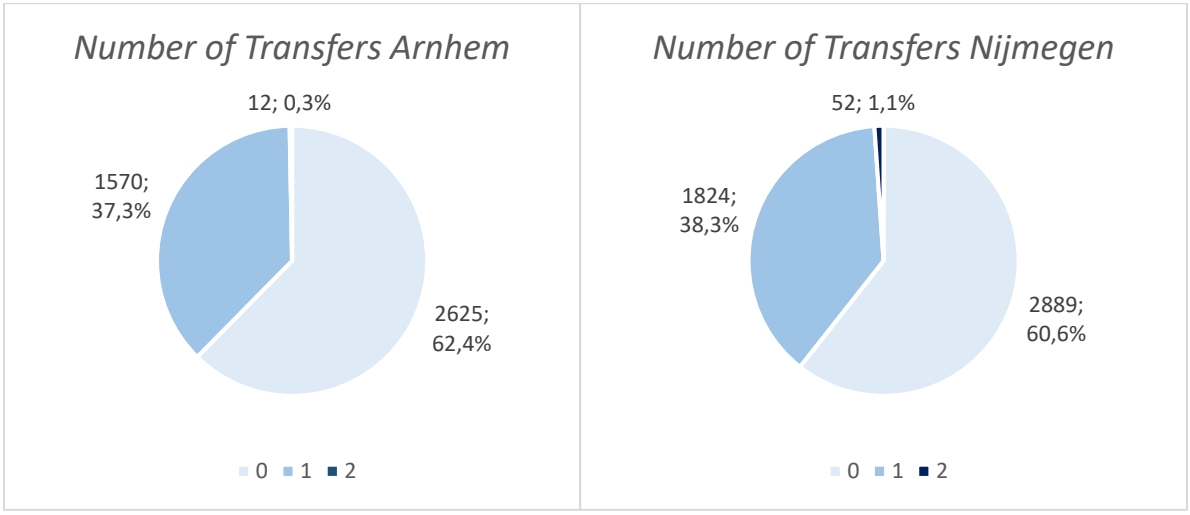

Figure 21 Public transport alternatives in number of transfers needed for Arnhem and Nijmegen (only walking alternatives counted as 0 transfers)

Two terms used in this analysis are "journey" and "travel". The journey duration stands for the total time, including waiting times, both by Breng Flex and public transport. The travel duration stands for the journey duration minus the wait between reservation and pickup in case of Breng Flex or the journey duration minus the wait before one should start walking or before the bus picks one up. The data, about the public transportation alternatives obtained from the API, contains distance of the journey, total travel duration, total journey duration, waiting duration before transit, waiting durations during transfers, walking durations before, walking durations during transfers, walking durations after the last transit and the number of transfers. Based on this data the perceived journey durations are calculated using the factors in Table 4 .

Table 4 Perceived time, factors used for public transport and Breng Flex

Attribute	Public Transport (factor)	Breng Flex (factor)
Waiting time before (expected)	* 2	* 2
Waiting time during transfers (expected)	* 2	-
Walking time	* 2	-
Number of transfers (to on-street bus)	10 minutes extra per transfer	-

3.3.2) Temporally gain for passengers

Other than the real time gain, the perceived time gain is also expressed. To get this perceived time gain, the factors have been used. The time gain is based on the whole journey including the waiting time before the travel starts. Firstly the table with the descriptive statistics for the rides in Arnhem (Table 5) and Nijmegen (Table 6) are given, containing the mean, median, standard deviation, minimum value, maximum value and the sample size. The 10^{th}, 25^{th}, 50^{th}, 75^{th} and 90^{th} percentile values are also calculated. In the second part the histograms can be found and are analyzed and discussed. Some Breng Flex rides are happening after and before the operation hours of regular public transport. Visible by high maximum waiting times in the tables The alternative by public transportation is then waiting for the earliest alternative in the morning. Sometimes these long waiting times avoided by using only walking alternatives.

Table 5 Breng Flex and public transport Arnhem temporal descriptive statistics

Arnhem	Waiting Time Public Transport [minutes]	Waiting Time Breng Flex [minutes]	Real time gain [minutes]	Perceived time gain [minutes]
Mean	8.31	9.32	14.30	27.48
Median	4.55	8.58	11.38	22.13
Standard Deviation	27.57	4.54	30.69	59.99
Minimum	0.00	0.50	-516.08	-506.62
Maximum	641.83	65.32	645.52	1303.97
N (sample size)	4207	4207	4207	4207
Percentile				
0.1	0.30	4.41	-1.72	-4.44
0.25	1.68	6.27	3.68	6.18
0.5	4.55	8.58	11.38	22.13
0.75	9.15	11.67	20.08	38.18
0.9	16.06	14.97	29.64	57.59

Table 6 Breng Flex and public transport Nijmegen temporal descripitve statistics

Nijmegen	Waiting Time Public Transport [minutes]	Waiting Time Breng Flex [minutes]	Real time gain [minutes]	Perceived time gain [minutes]
Mean	8.33	9.43	17.25	35.20
Median	5.55	8.73	14.75	30.13
Standard Deviation	10.62	4.47	16.30	33.80
Minimum	0.00	0.65	-42.75	-48.25
Maximum	103.15	59.03	133.70	270.10
N (sample size)	4765	4765	4765	4765
Percentile				
0.1	0.37	4.67	0.68	0.31
0.25	1.90	6.32	7.08	12.98
0.5	5.55	8.73	14.75	30.13
0.75	10.72	11.83	24.02	50.33
0.9	17.73	15.19	35.23	72.14

In Arnhem (Table 5) the average waiting time for Breng Flex is one minute (12.2 %) longer than for public transport, 9.32 minutes versus 8.31 minutes. The medians differs more than the means, again in favor of the public transport, 8.58 minutes versus 4.55 minutes (88.6 % longer for Breng Flex). The median is better than the mean due to the skewness of the public transport distribution, that when no reasonable alternative is found, gives you an extreme waiting time. Between the 75th and 90th percentile, the waiting time for public transport becomes longer than for Breng Flex. So, more than 10 percent, but less than 25 percent of the rides by Breng Flex have a shorter waiting time than public transport.

In Nijmegen (Table 6), the average waiting times are similar to Arnhem, the average waiting time for Breng Flex is about one minute (13.2 %) longer than for public transport, 9.43 minutes versus 8.33 minutes. The medians again differs more than the means in favor of the public transport, 8.73 minutes versus 5.55 minutes (57.3 % longer for Breng Flex), which is a smaller difference than in Arnhem. However the maximum waiting duration for public transport is 103 minutes versus 59 minutes for Breng Flex. Similar to Arnhem, the waiting time for public transport becomes longer than for Breng flex between the 75th and 90th percentile. So, more than 10 percent, but less than 25 percent of the rides by Breng Flex have a shorter waiting time than public transport.

The histograms for the real waiting times in Arnhem and Nijmegen (Figure 22) show the waiting times for public transport and Breng Flex for the two cities. The highest frequency of waiting times for public transport is around 2 minutes for both cities. Going to the right in the histogram, the number of journeys decreases fast. Only a few journeys have waiting times over 20 minutes, 6.8 % of the alternatives (285 journeys) in Arnhem and 8.0 % of the alternatives (380 journeys) in Nijmegen. For waiting times over 30 minutes, the number of journeys decreases to 2.6 % of the alternatives (108 journeys) in Arnhem and 3.6 % of the alternatives (172 journeys) in Nijmegen.

The highest frequency of waiting times for Breng Flex is around 8 minutes for both cities (Figure 22). In comparison to public transport, even less journeys have a waiting time of over 20 minutes, only 2.3 % of the rides (96 rides) in Arnhem and 2.0 % of the rides (97 rides) in Nijmegen. Waiting times of over 30 minutes are very rare, only 0.3 % of the rides (11 rides) in Arnhem and 0.2 % of the rides (9 rides) in Nijmegen. Because Breng Flex require a reservation before a vehicle arrives, the waiting times are the durations that drivers need to drive to the required stop. These frequencies could be shifted more to the left if the vehicles of Breng Flex are more spread out through the city, perhaps even with more vehicles to be able to arrive earlier at the stops to pick-up passengers.

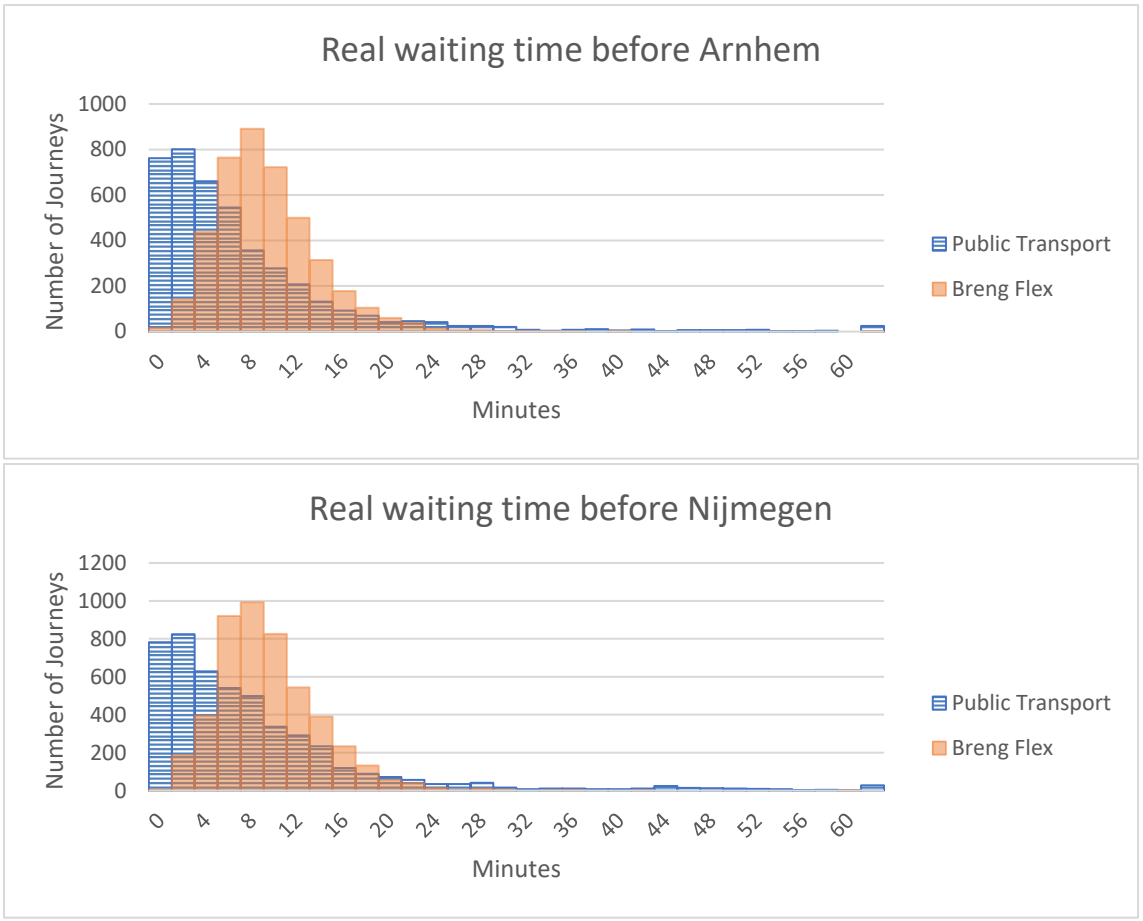

Figure 22 Histogram of real waiting times before in Arnhem (above) and Nijmegen (below)

In Arnhem (Table 5) the real time gain of Breng Flex, based on the time of reservation till the time of arrival, is on average 14.30 minutes. The median is 11.38 minutes, in the data are some outliers with much time gain, raising the average. 14.3 % of the rides (602 rides) by Breng Flex result in real time loss. On the other hand, 54.5 % of the rides (2294 rides) by Breng Flex saves more than 10 minutes. The perceived time gain of Breng Flex, calculated using the factors preciously explained, is on average 27.48 minutes, 92.2 % higher than the real time gain. The median is 22.13 minutes, 94.5 % higher than the real time gain. Notable is that the real and perceived maximum time loss decreases only 1.8 %, while the real and perceived maximum time gain increases 102.0 %. Showing that in some rides Breng Flex could be perceived much shorter than they are in reality. 15.4 % of the rides (649 rides) by Breng Flex result in perceived time loss. On the other hand, 69.2 % of the rides (2910 rides) by Breng Flex results in more than 10 minutes perceived time gain.

In Nijmegen (Table 6) the real time gain of Breng Flex, based on the time of reservation till the time of arrival, is on average 17.25 minutes. The median is 14.75 minutes, in the data are some outliers with much time gain, raising the average. 8.8 % of the rides (418 rides) by Breng Flex, result in real time loss. However for 66.1 % of the rides (3148) by Breng Flex more than 10 minutes are saved. The perceived time gain of Breng Flex, based on the time of reservation till the time of arrival, is on average 35.20 minutes, 104.1 % higher than the real time gain. The median is 30.13 minutes, 104.3 % higher than the real time gain. Notable is that the real and perceived maximum time loss increases only 12.9 %, while the real and perceived maximum time gain increases 102.0 %. Showing that in some rides Breng Flex could be perceived much shorter than they are in reality. 9.7 % of the rides (461 rides) by Breng Flex result in perceived time loss. On the other hand, 79.0 % of the rides (3766 rides) by Breng Flex results in more than 10 minutes perceived time gain.

The histograms for the time gain of the journeys in Arnhem and Nijmegen (Figure 23) show real and perceived time gains of Breng Flex for the journeys. The last column in the histograms are the journeys with more than 60 minutes time gain. This column is truncated at 350 journeys to make the other columns better visible, but in reality there were 366 journeys for Arnhem and 755 journeys for Nijmegen. The perceived duration of journeys with Breng Flex assumes that the waiting time for Breng Flex is expected. If this is not the case, the perceived time gain is much lower. Expected waiting times have a perceived penalty factor 2 and unexpected waiting times have a perceived penalty factor 5 (19). So 8 minutes waiting time is now assumed perceived as 16 minutes in the journey duration, but when assuming an unexpected waiting time of 8 minutes this would become 40 minutes in the journey duration.

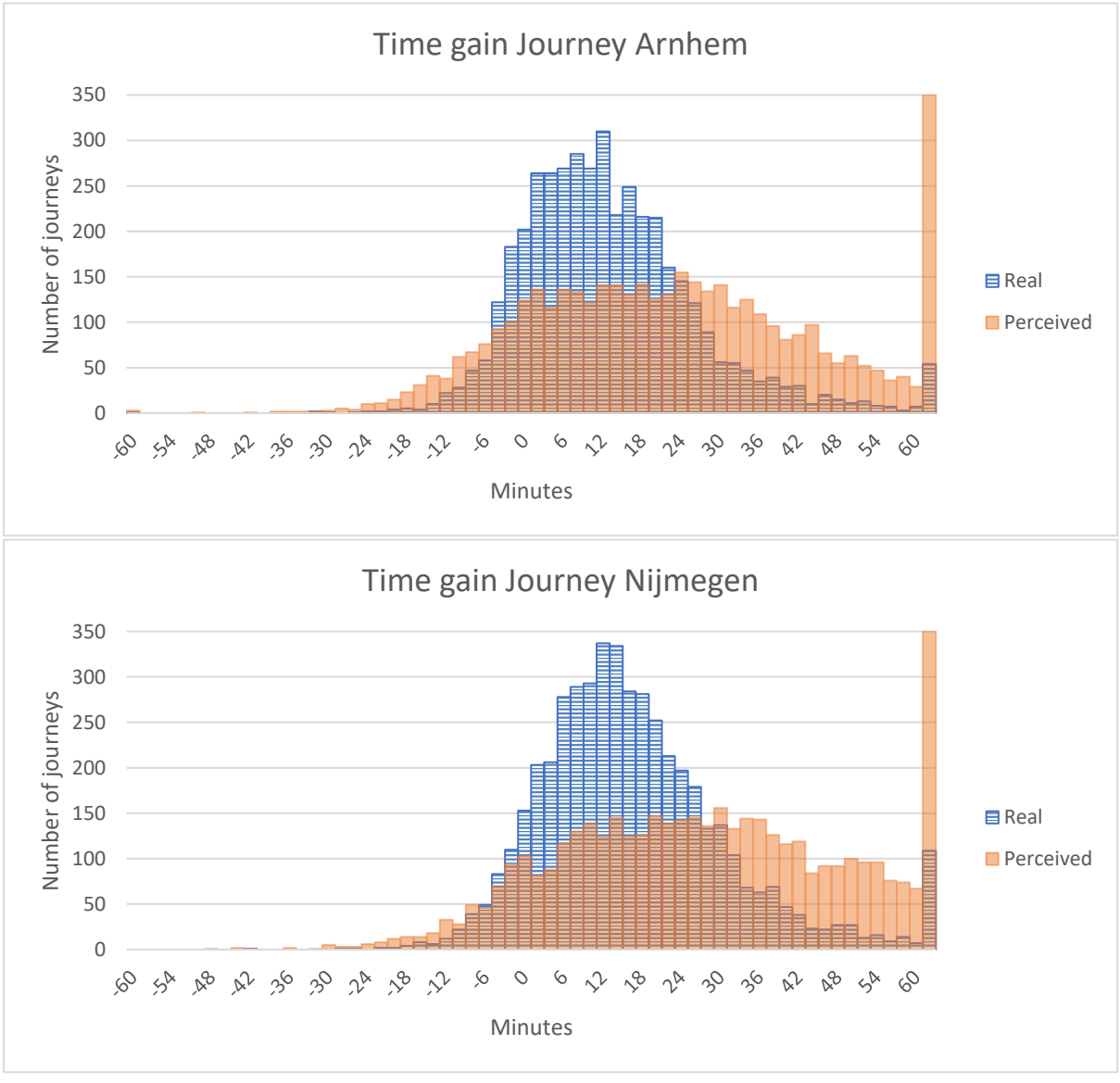

Figure 23 Histogram of time gain in Arnhem (above) and Nijmegen (below)

3.3.3) Summary

The real and perceived time gain when using Breng Flex in comparison to regular public transport alternatives is significantly shorter. Also, 38 % of the rides saved one or two transfers for the passengers. The real time gain is on average 14.3 minutes and the average perceived time gain is even higher with 27.5 minutes. The means and medians of the waiting times before the travels are significant longer for Breng Flex than for the regular public transport.

4) Conclusion

4.1) Key findings

4.1.1) Spatial

Breng Flex has been used in the whole area. Almost all stops have been used, only 15 out of 258 stops in Arnhem and 8 out of 255 stops in Nijmegen have not been used during the evaluated period. Every train station in the areas is served by Breng Flex. The demand is high around the central train stations. Also worth mentioning is the frequent usage of Breng Flex at "Camping/Manege De Maesberg, Arnhem", "Ziekenhuis Rijnstate, Arnhem" and "OBG, Nijmegen". Breng Flex is used for regular leisure activities, for (regular) appointments at the doctor and by the elderly (paratransit). Some passengers regularly take the same rides. In both regions, a hotspot is visible in the center of the main cities. In Nijmegen Breng Flex is also often used between Nijmegen and Wijchen.

4.1.2) Demand

The demand is still growing and Breng Flex currently has a sufficient capacity to keep the average waiting time below 10 minutes. The total demand in number of rides has increased rapidly, in comparison to the previous month, with 31 % in March and 65 % in April. On Kingsday, April 26th, Breng Flex is used for 139 rides, the busiest day of Breng Flex so far. Every month, an increasing amount of people is trying out Breng Flex. Also increasing is the share of the rides by Breng Flex that are used by the regular customers. So Breng Flex has changed the preference of travel mode of passengers. In contrast to the high peaks during rush hours in the morning in other modes of transport, the demand of Breng Flex stays noticeable similar throughout the day.

4.1.3) Rides

The performance has remained steady, even with the increase in demand. Nijmegen has longer rides than Arnhem (on average), this results in longer rides in Nijmegen and thus similar average speeds. However, the average waiting time for Breng Flex is not longer in Nijmegen and was in the past months constant 9 to 10 minutes. The average distances also stayed constant in the past months. The in-vehicle time delays of Breng Flex are limited. Only 8.1 % of the rides with Breng Flex had a delay of 5 minutes or more, making Breng Flex a reliable alternative travel mode.

4.1.4) First and last mile solution

Breng Flex may have been used as a first or last mile solution in combination with rail for up to 20 % of the rides. These rides start or end at a train station. More rides are departing from train stations (10.6 %) than arriving at train stations (8.6 %). 77.7 % of the departures are departing from the 3 most used train stations (CS Arnhem, CS Nijmegen, Dukenburg Nijmegen). For these stops with a lot of departures, a Breng Flex vehicle on standby at that location would be convenient for the passengers.

4.1.5) Comparison to regular public transport

The real and perceived time gain when using Breng Flex in comparison to regular public transport alternatives is significantly shorter. Also, 38 % of the rides saved one or two transfers for the passengers. The real time gain is on average 14.3 minutes and the average perceived time gain is even higher with 27.5 minutes. The means and medians of the waiting times before the travels are significant longer for Breng Flex than for the regular public transport.

4.2) Limitations

To understand the results better, the limitations must be known. The data of Breng Flex is only about the first six months of operation. The Breng Flex service could have achieved a higher ridership at a more mature and steady state of this service. However, this would be the case for every new DRT services and thus making results comparable. The data lacked the records of the sub-contractors so

only about 60 % of the total rides were available and used for this thesis. Including the records of these sub-contractors would influence the results. The studied data also have some outliers and which records exactly, was unknown. So they are left in the data.

The data for the public transport was obtained using the Google Directions API. The alternative reported back contained the schedule times, instead of the real times with delays. So the times for public transport were probably slightly idealized. Also, the alternative with the earlies arrival time was chosen based on the reservation time. When journeys could be planned forward, public transport would come out more positively.

Before the implementation of Breng Flex, some fixed lines were cancelled. This was partly done to see how people were reacting on Breng Flex with the lack of the fixed line. However, based on the data in this thesis it is unknown if users were from the fixed line or new users of public transport. Besides it is unknown from which modes the users came from, so the increase of the accessibility in the areas could not be determined.

The studied data is geographically only about the region Arnhem and Nijmegen. There is not enough evidence that Breng Flex would behave similarly in other settings. The financial part is ignored in this thesis, but for a viable urban DRT service, its profitability is an important part to research.

4.3) Recommendations

For future evaluation of Breng Flex, the data could be controlled for outliers, making the data of Breng Flex more reliable. Also, the records for the subcontractors could be included to get a complete picture. A recommendation for Breng Flex would be to keep track of the waiting times, with the fast growth of Breng Flex, it is likely that the capacity of the current fleet won't be sufficient anymore after a while. With a high enough demand, a larger fleet of vehicles could also mean a decrease in the waiting times. It will be more likely that another passenger is also doing approximately the same ride at the same time. Pre-order a ride by Breng Flex is a very wanted feature. However from the system design perspective this will decrease the efficiency of a limited size fleet, because reserving a vehicle some time before the pick-up just to drive to and wait for a passenger is not efficient (7).

Urban DRT is still not fully understood. The pilots in the past were mostly paratransit (DRT for disabled and elderly). In general for future research, the data of the public transport alternatives could be obtained with the real times with delays instead of the schedule times, resulting in a more accurate travel time. Also the alternative with the shortest duration could be used, instead of the alternative with the earliest arrival time, to compare the duration of the travels instead of the duration of the journeys. More research is also needed to find out from which modes the users came from. This will be useful to see if urban DRT could increase the share of public transport, or that urban DRT is only a competitor for regular public transport. Determining the change in accessibility in the areas with urban DRT will be interesting to see the potential of urban DRT to better socially include parts of the city or villages. The profitability of urban DRT could also be interesting to include in future researches.

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Appendices

Appendix A: Network flow visualization for Arnhem and Nijmegen

Figure A.1 Network flow visualization of Arnhem

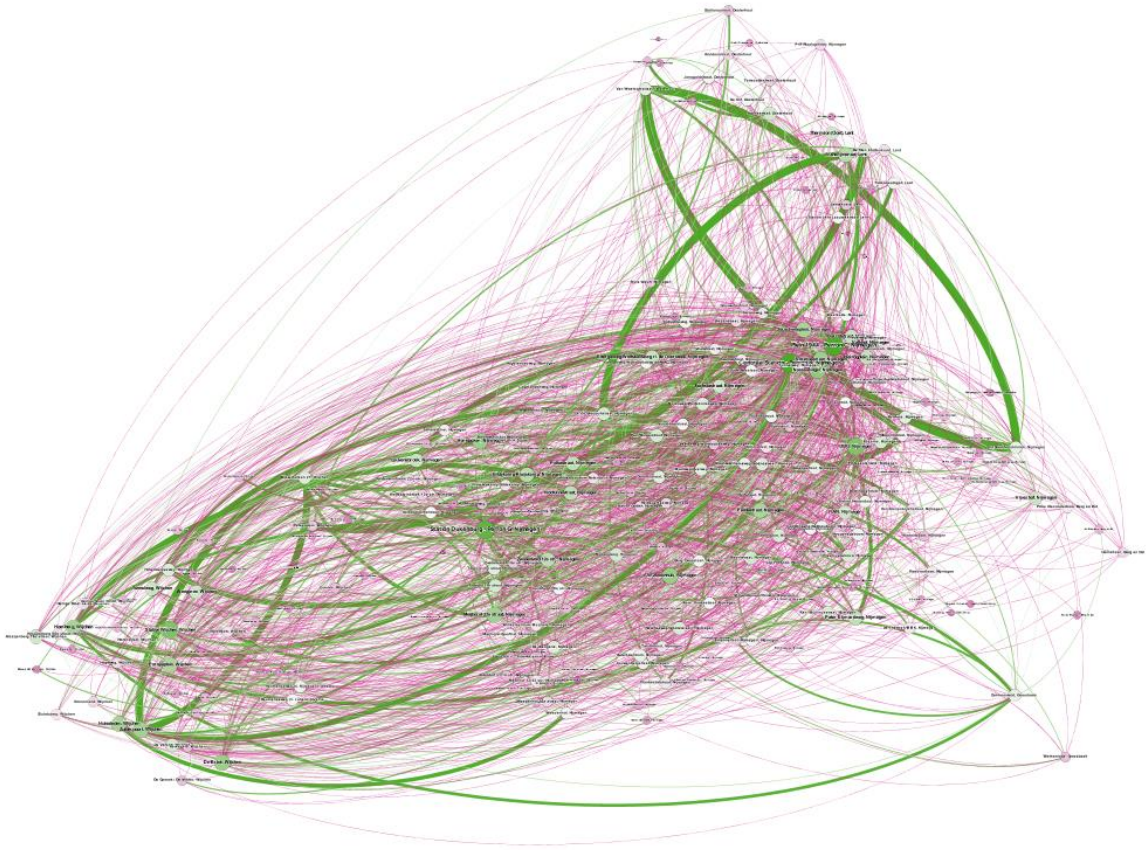

Figure A.2 Network flow visualization of Nijmegen

Appendix B: Breng Flex performance and usage demand per week

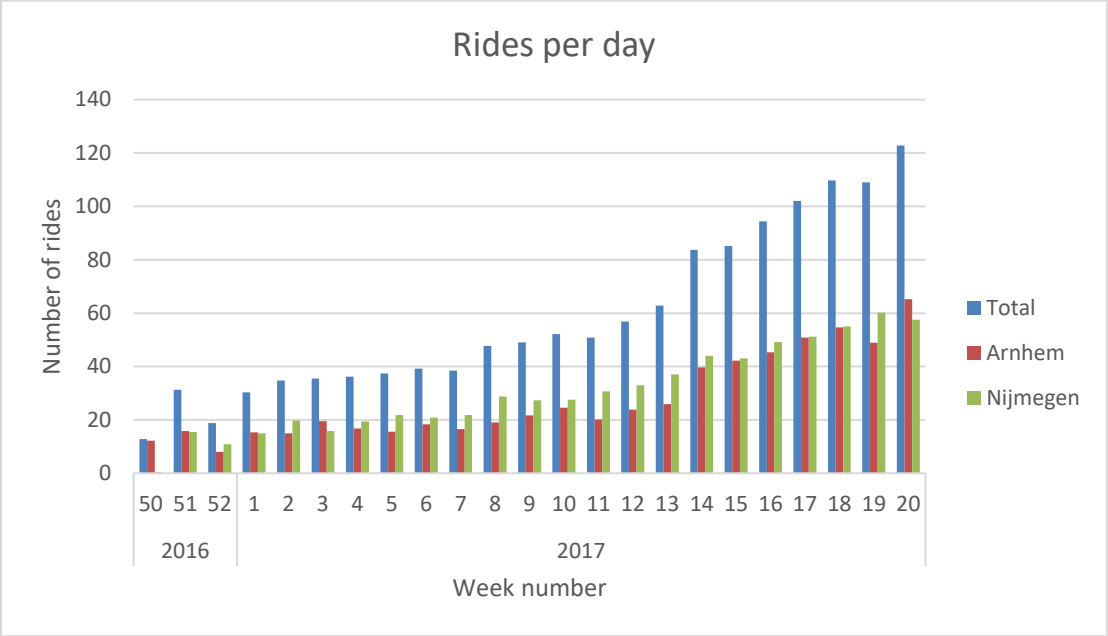

Figure B.1 Average number of rides each day per week

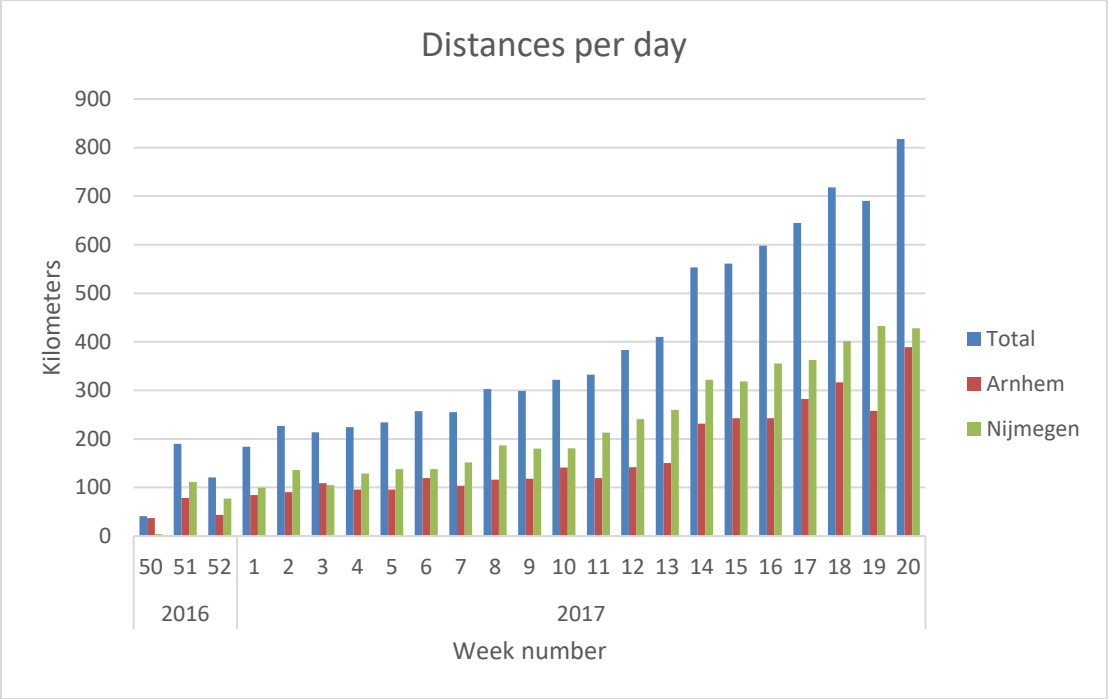

Figure B.2 Average kilometers each day per week

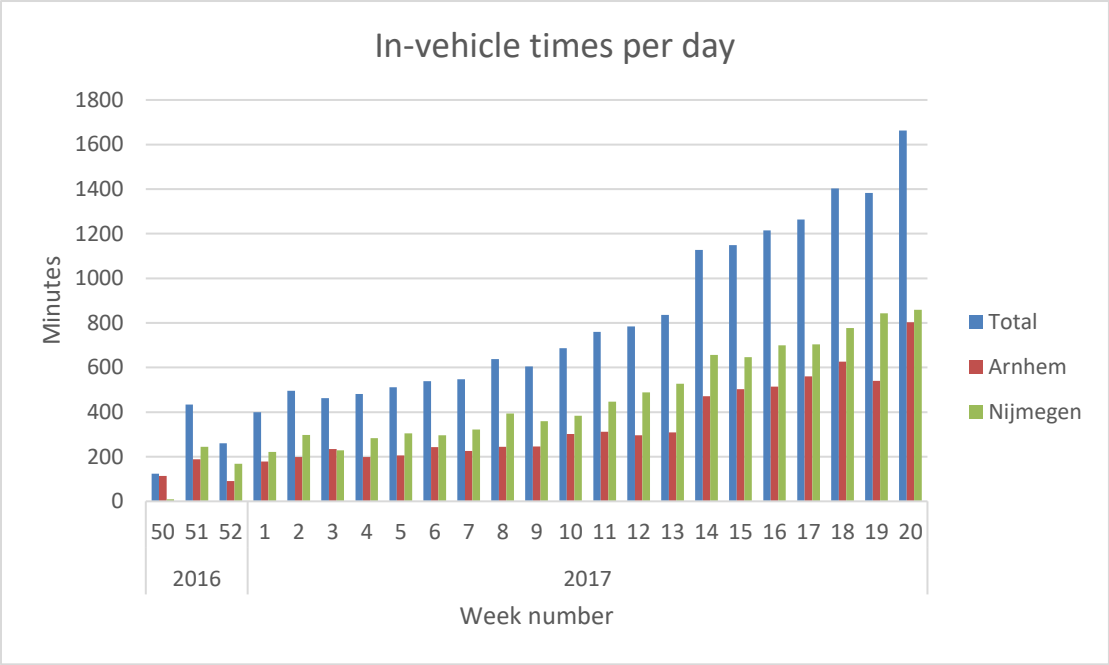

Figure B.3 Average in-vehicle time each day per week

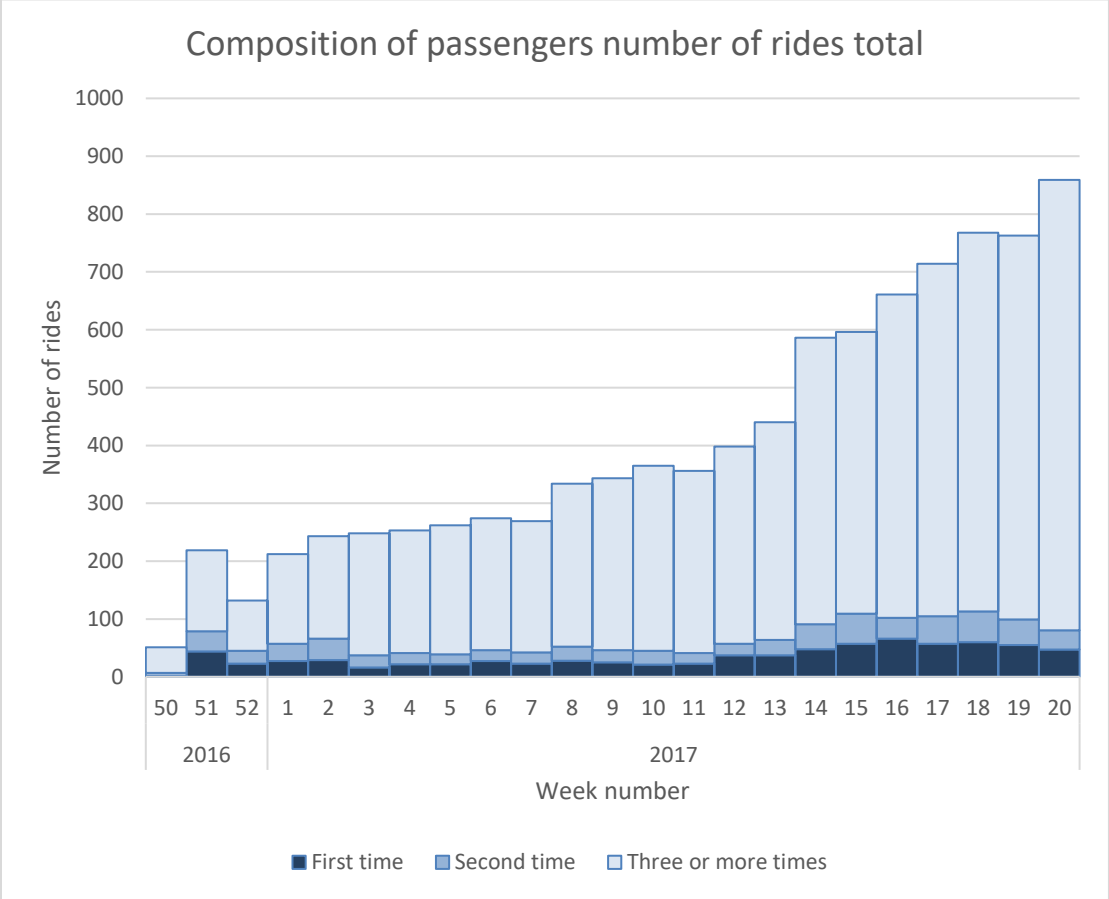

Figure B.4 Composition of passengers in number of times user of Breng Flex for both regions per week

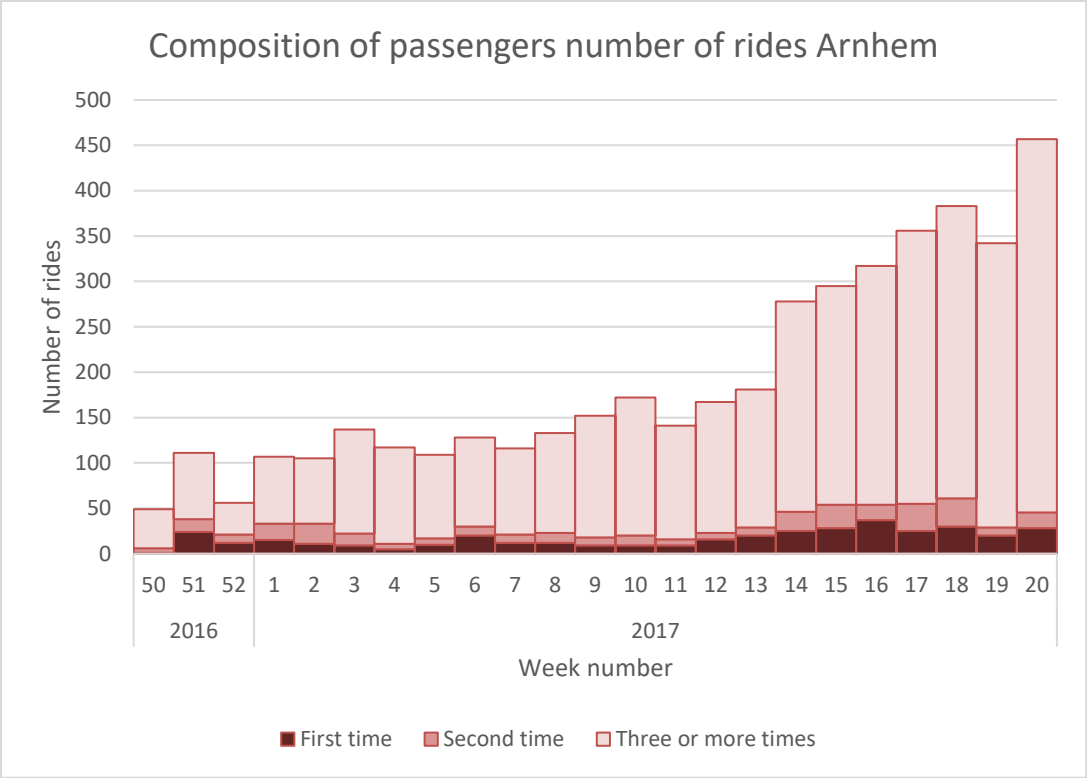

Figure B.5 Composition of passengers in number of times user of Breng Flex for Arnhem per week

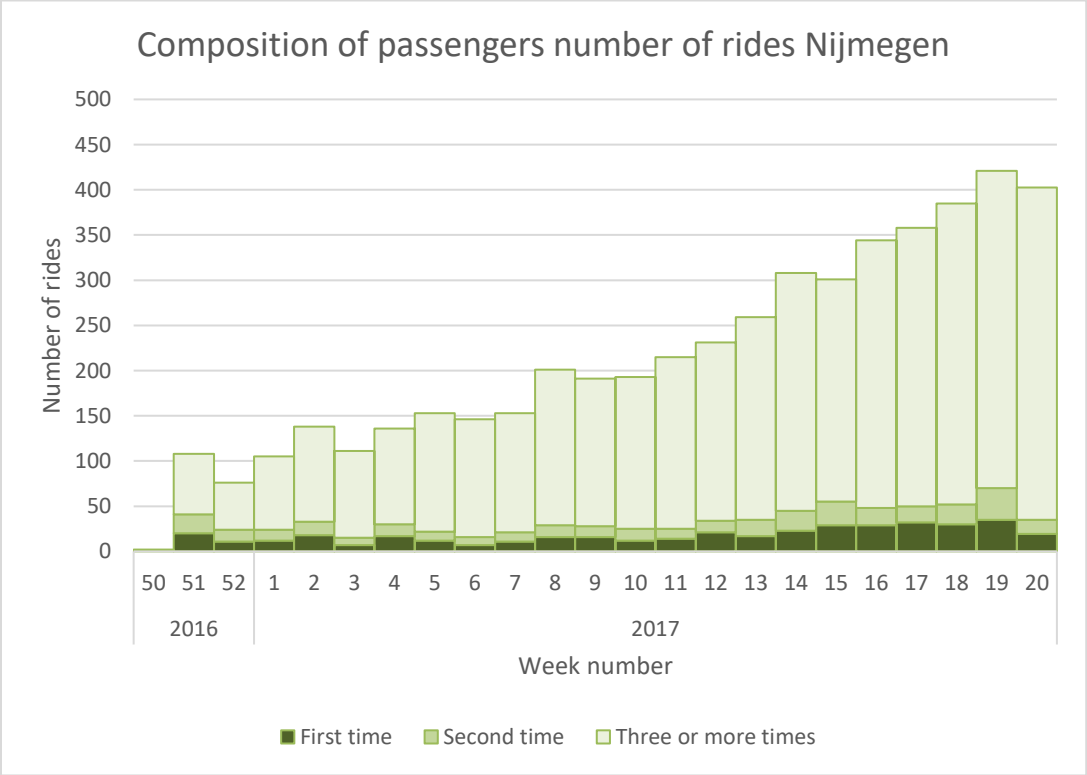

Figure B.6 Composition of passengers in number of times user of Breng Flex for Nijmegen per week

Appendix C: Breng Flex performance and usage demand per hour

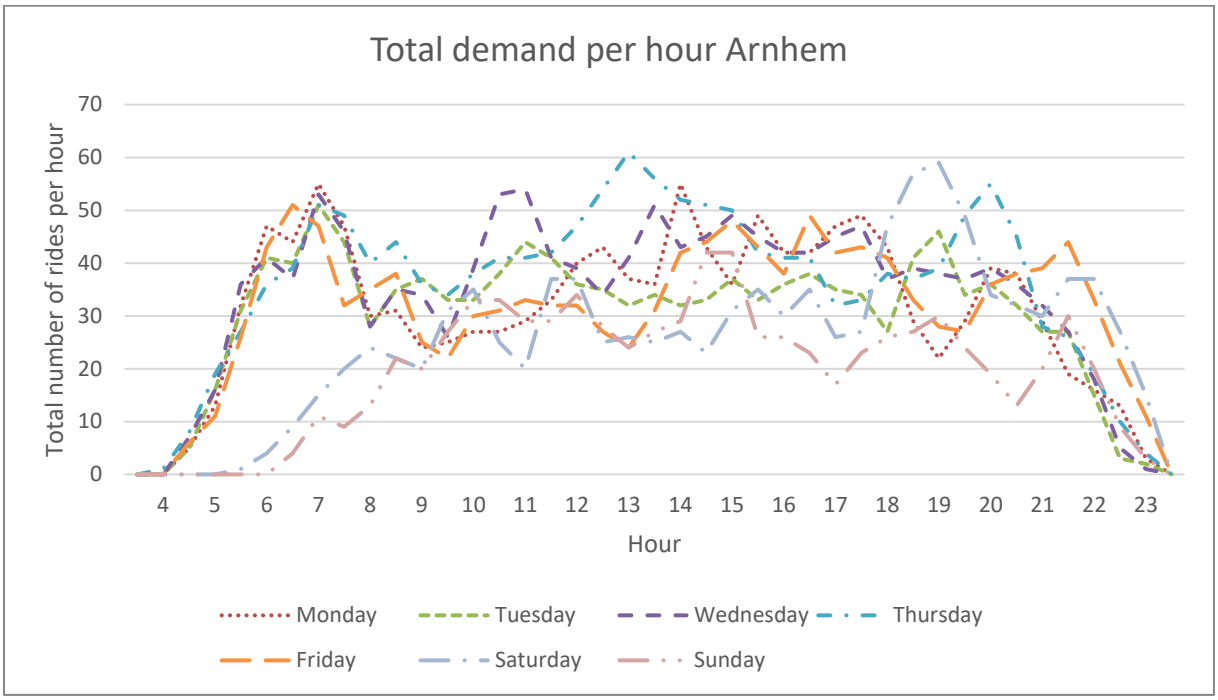

Figure C.1 Demand per hour for Arnhem (total number of rides of the first 5 months)

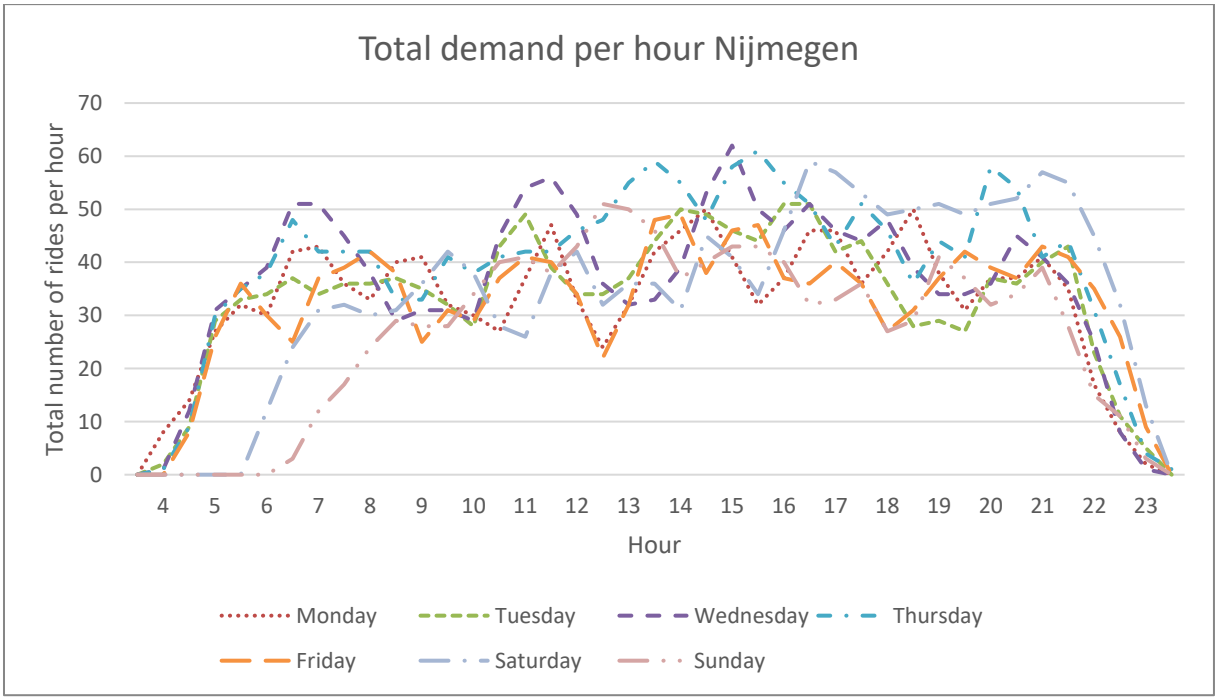

Figure C.2 Demand per hour for Nijmegen (total number of rides of the first 5 months)

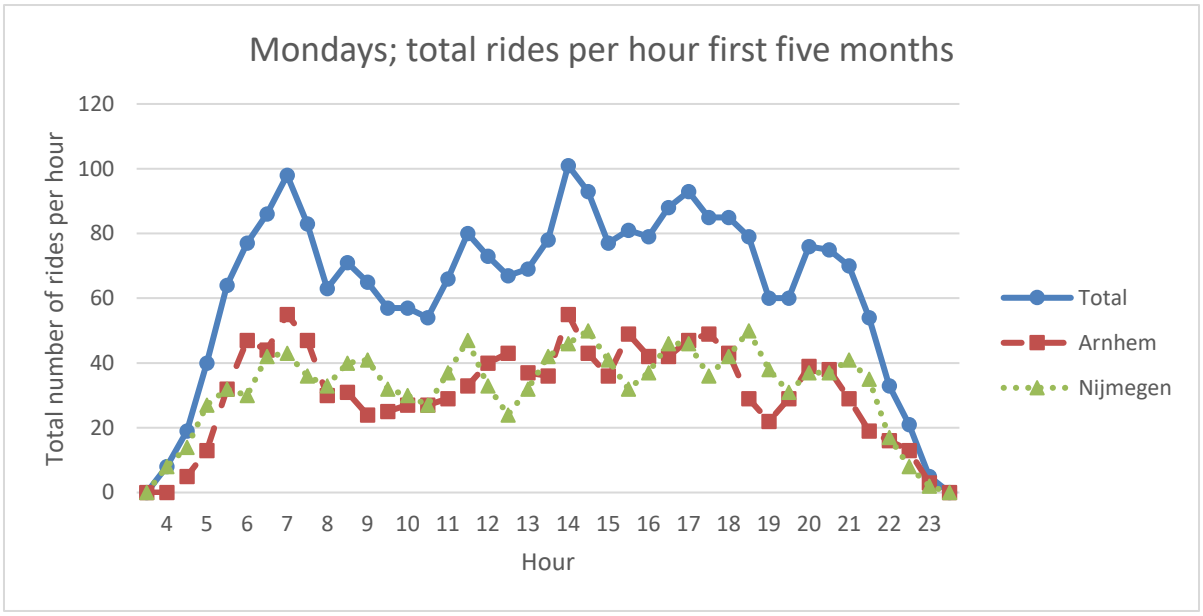

Figure C.3 Demand per hour Mondays (total number of rides of the first 5 months)

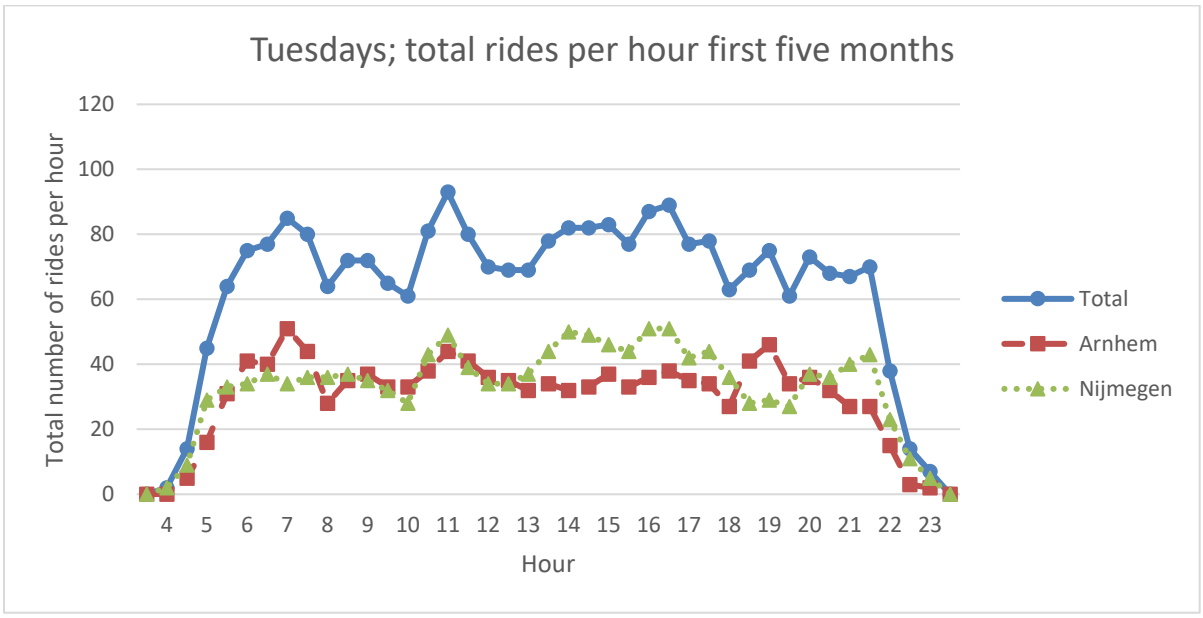

Figure C.4 Demand per hour Tuesdays (total number of rides of the first 5 months)

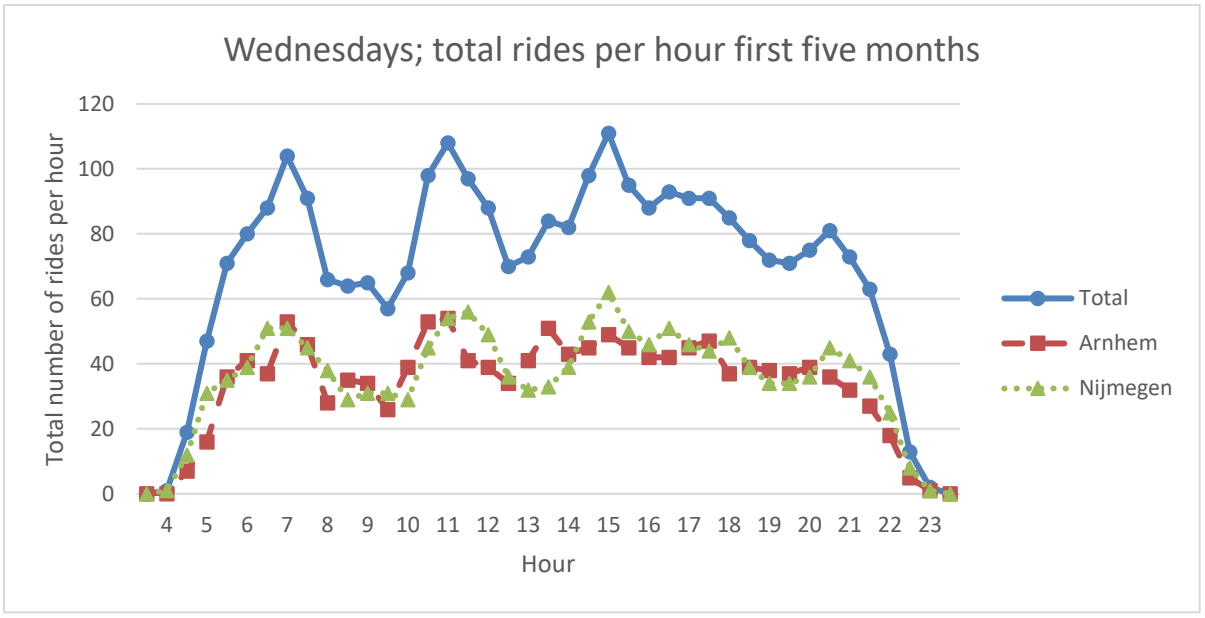

Figure C.5 Demand per hour Wednesdays (total number of rides of the first 5 months)

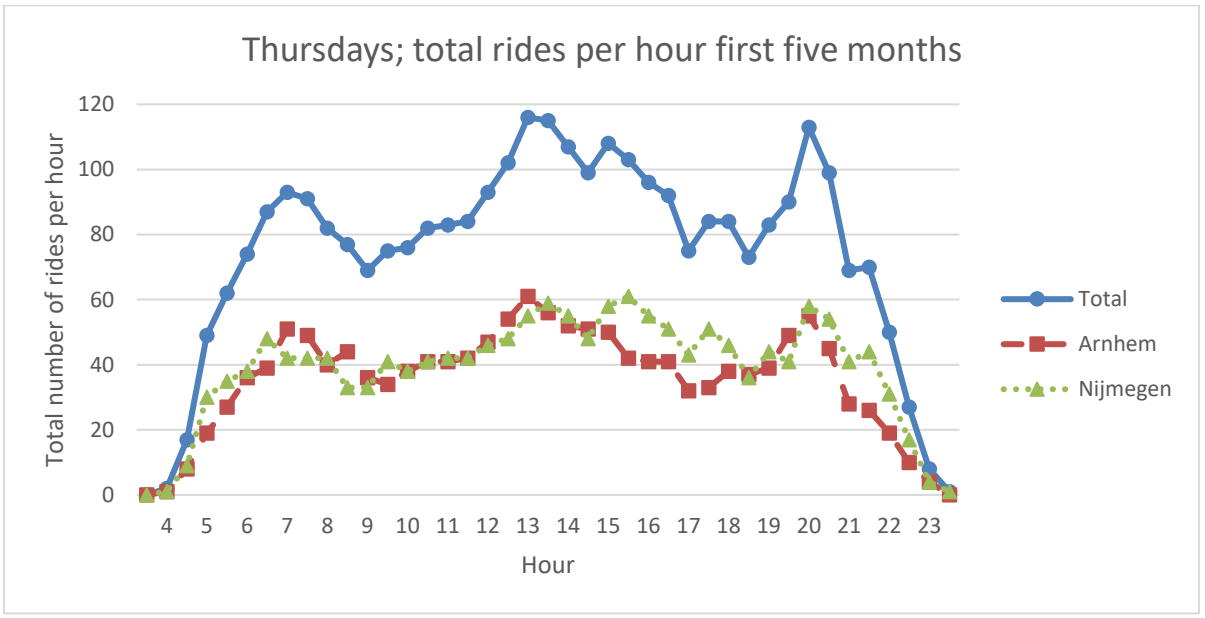

Figure C.6 Demand per hour Thursdays (total number of rides of the first 5 months)

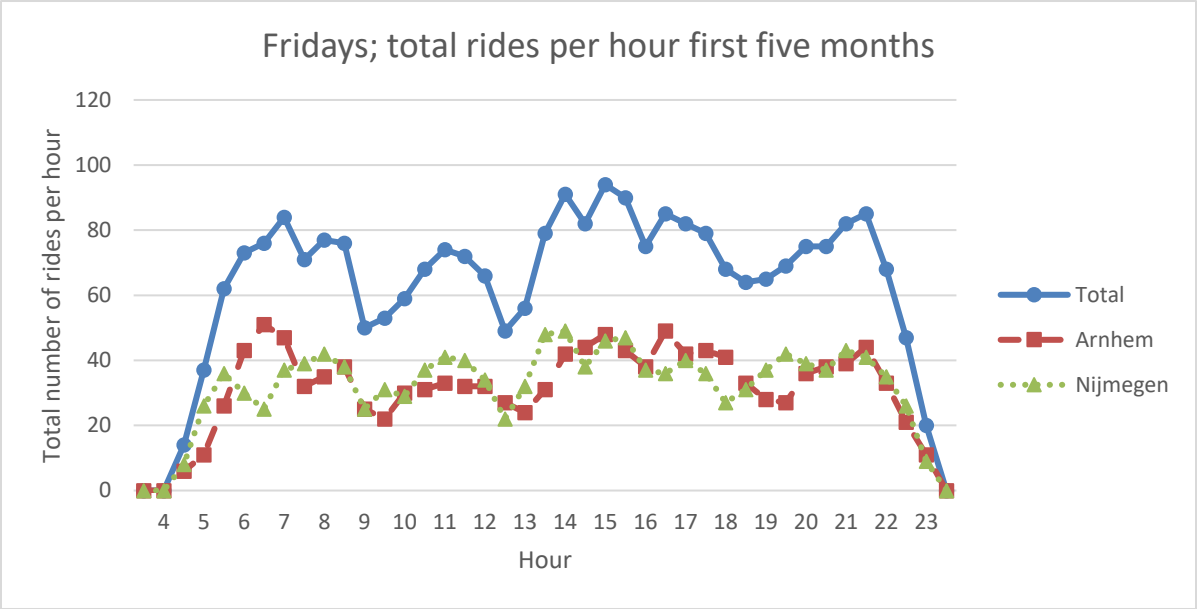

Figure C.7 Demand per hour Fridays (total number of rides of the first 5 months)

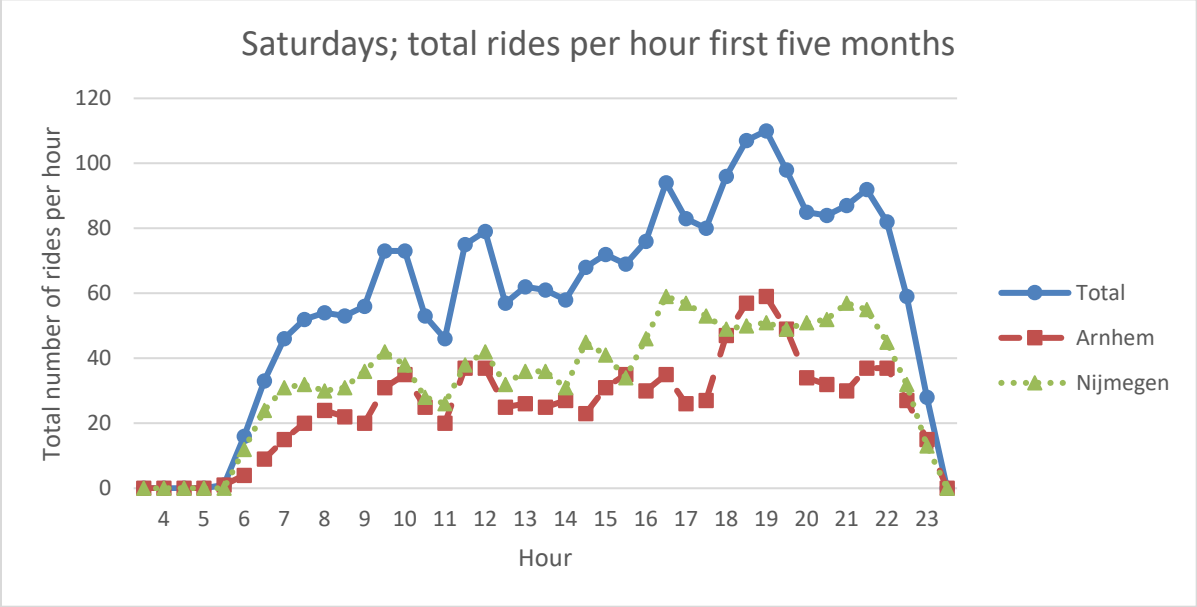

Figure C.8 Demand per hour Saturdays (total number of rides of the first 5 months)

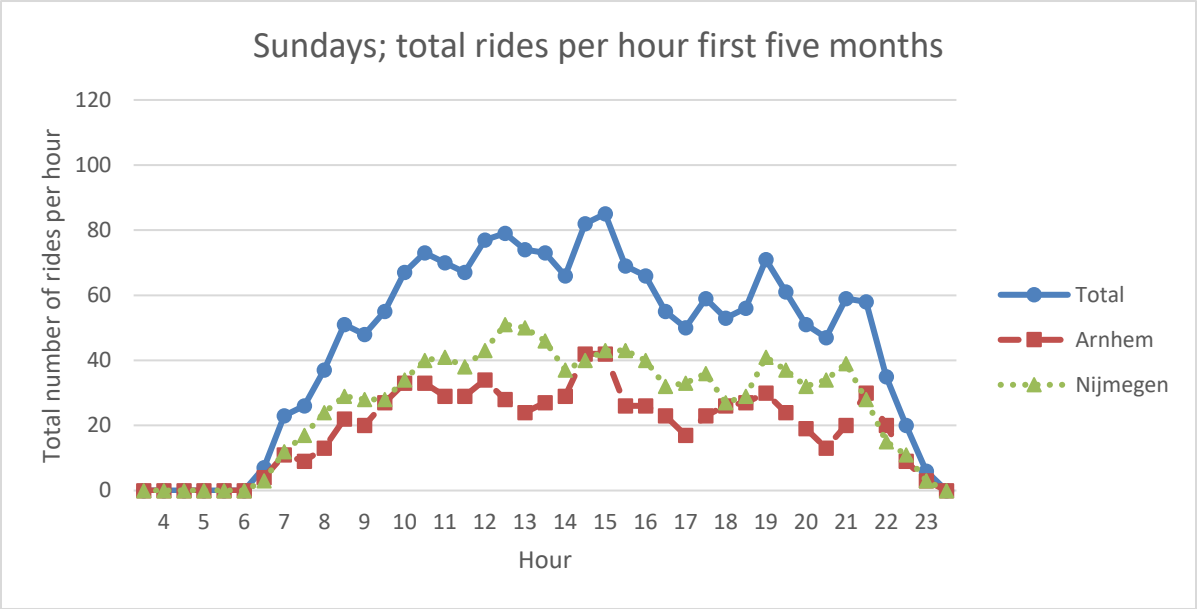

Figure C.9 Demand per hour Sundays (total number of rides of the first 5 months)

Appendix D: Breng Flex performance and usage of the rides per week

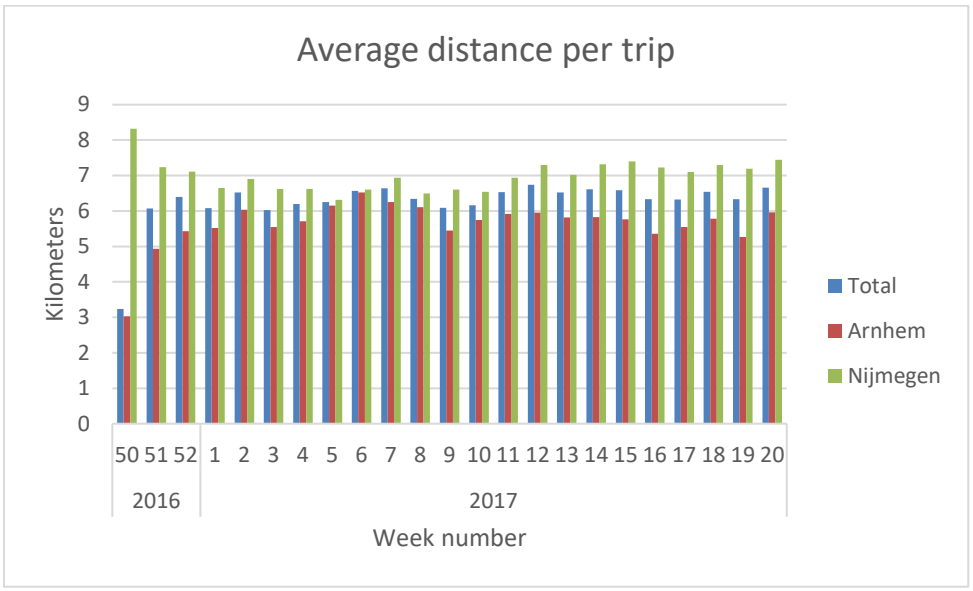

Figure D.1 Average kilometers per ride per week

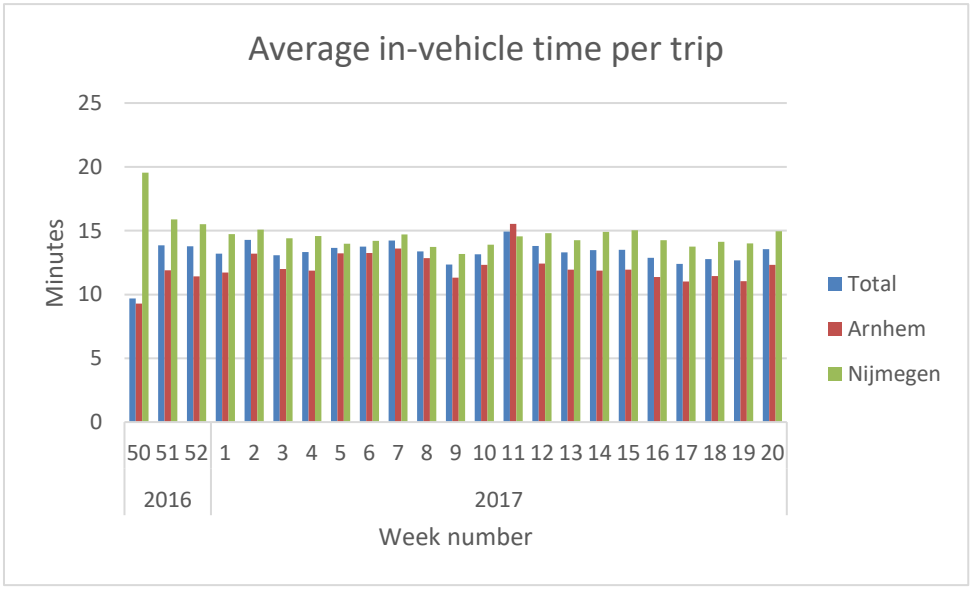

Figure D.2 Average in-vehicle time per ride per month

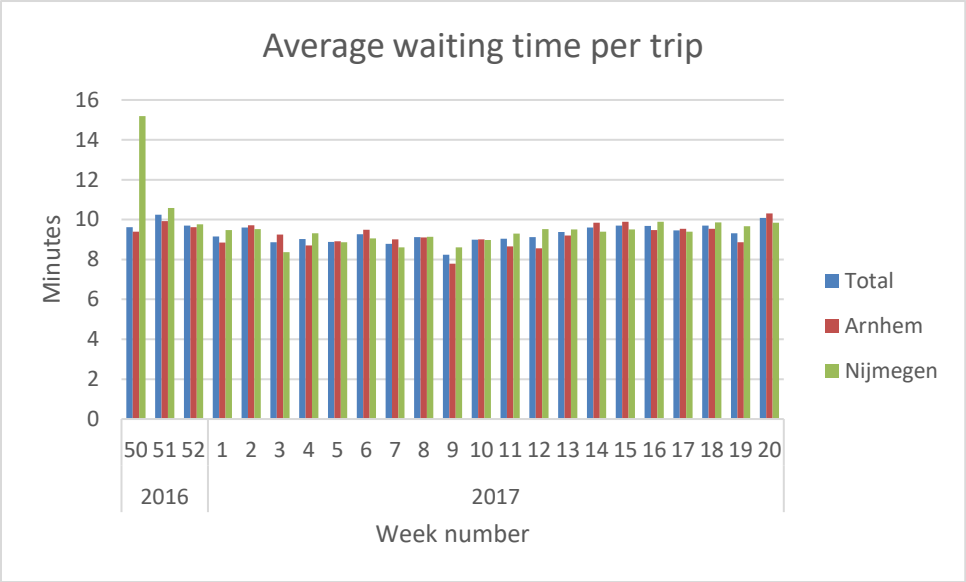

Figure D.3 Average waiting time per ride per month

Appendix E: Breng Flex distribution of the average speed [0-120 km/h]

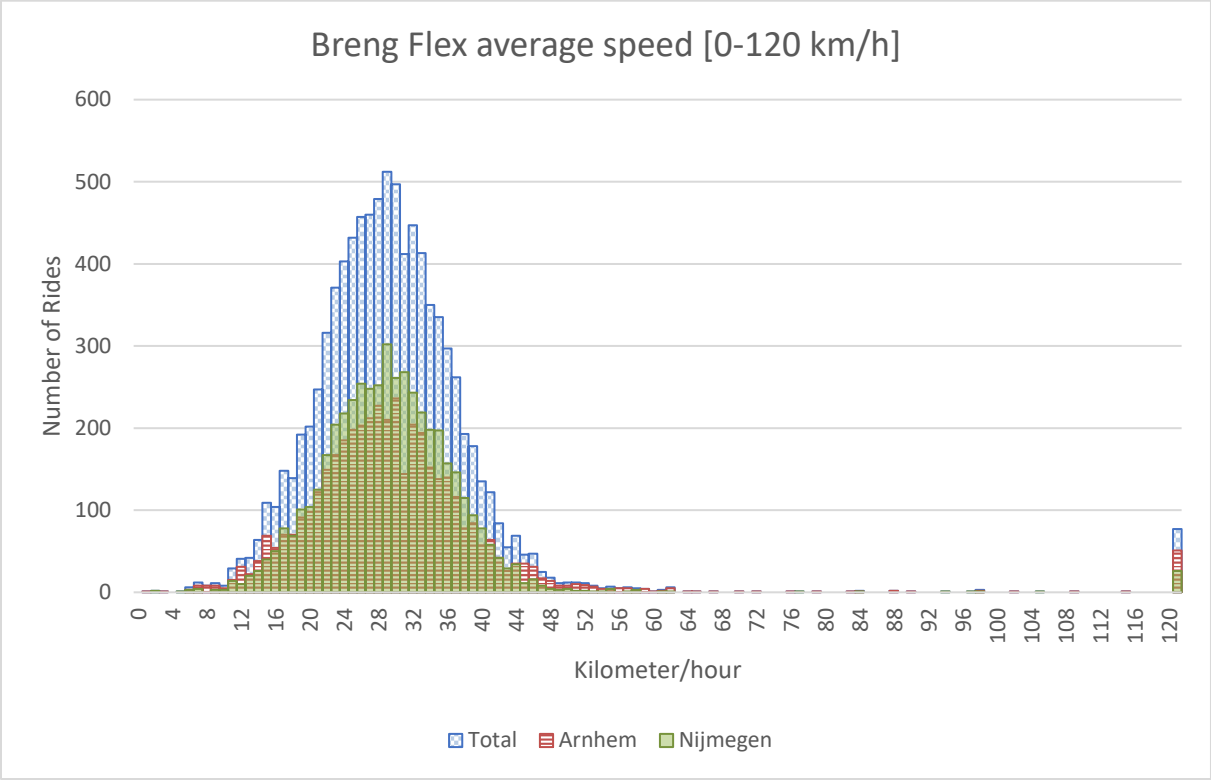

Figure E.1 Breng Flex Distribution Average Speed [0-120 km/h]

Appendix F: Breng Flex comparison with only walking alternatives

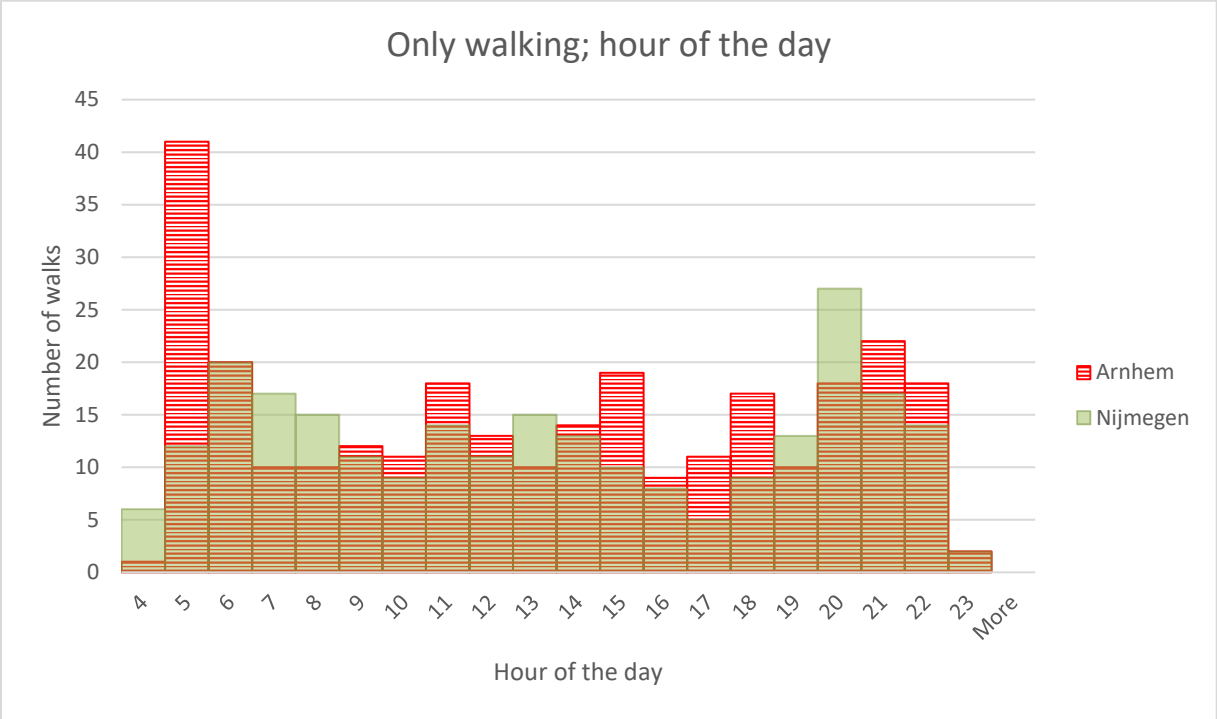

Figure F.1 Number of only walking alternatives by public transport in Arnhem and Nijmegen per hour of the day

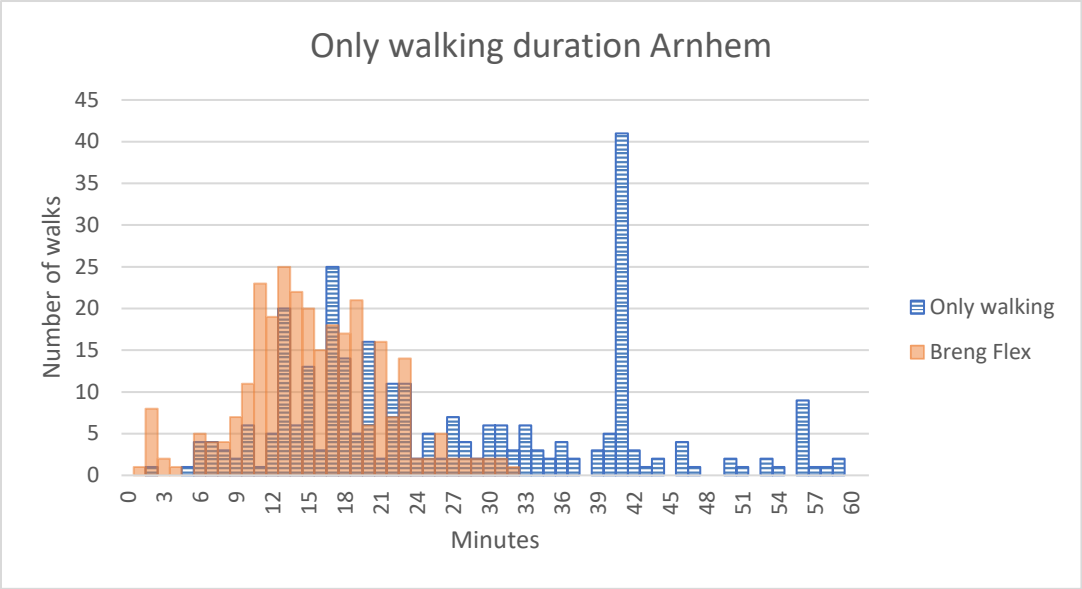

Figure F.2 Distribution of durations of only walking alternatives in Arnhem

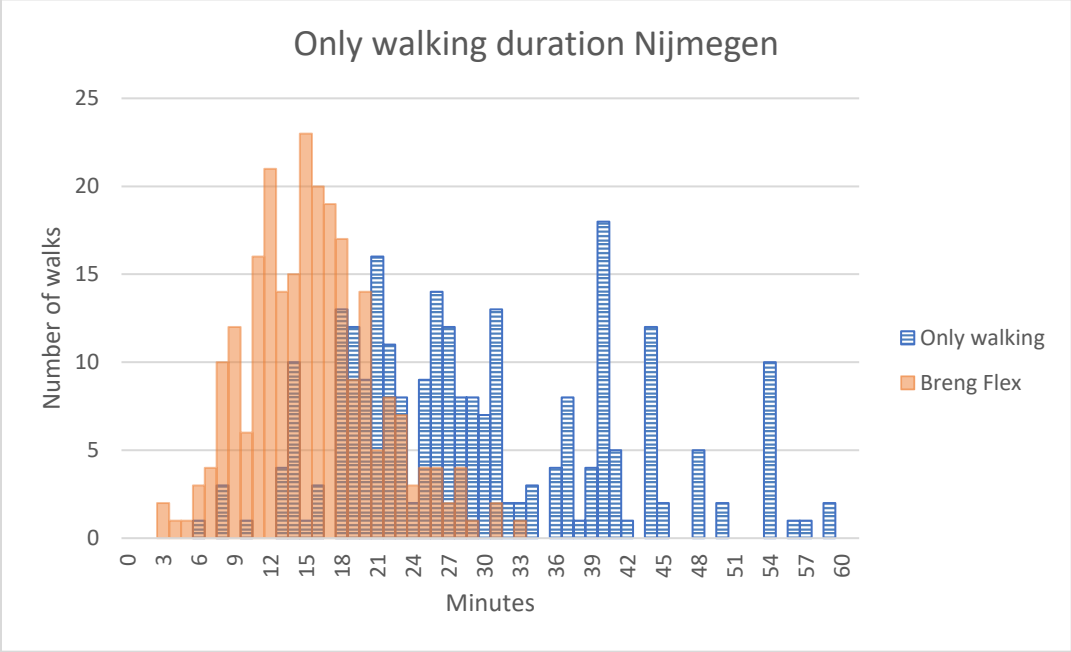

Figure F.3 Distribution of durations of only walking alternatives in Nijmegen

Appendix G: Breng Flex comparison with public transport distribution of the real travel duration and real and perceived journey durations

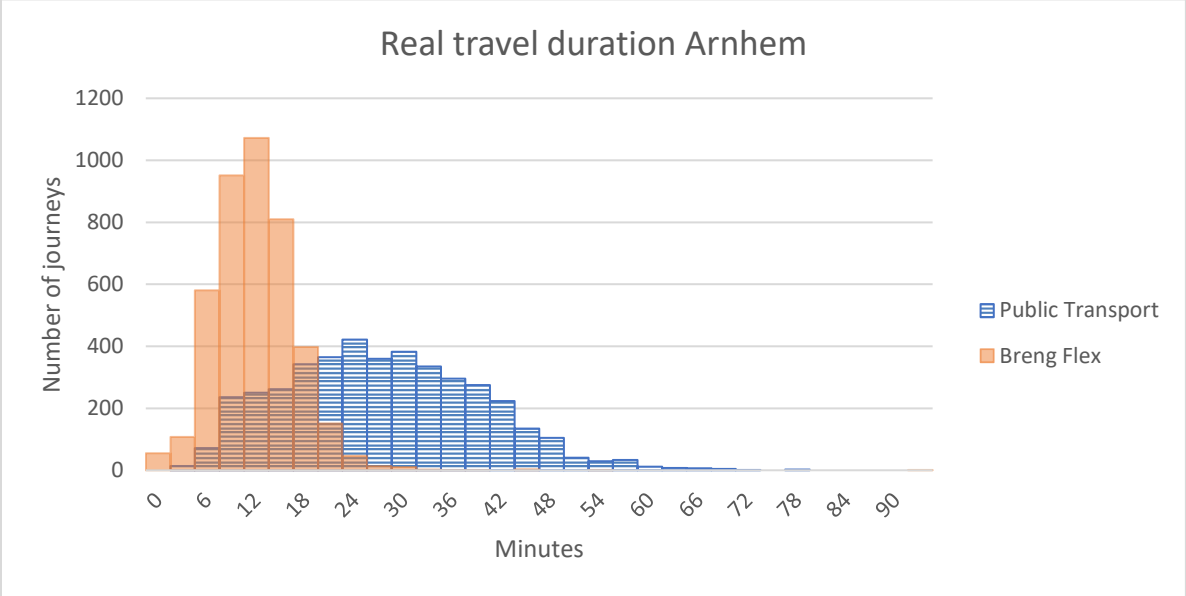

Figure G.1 Distribution of real travel durations in Arnhem of Breng Flex and the public transport alternatives

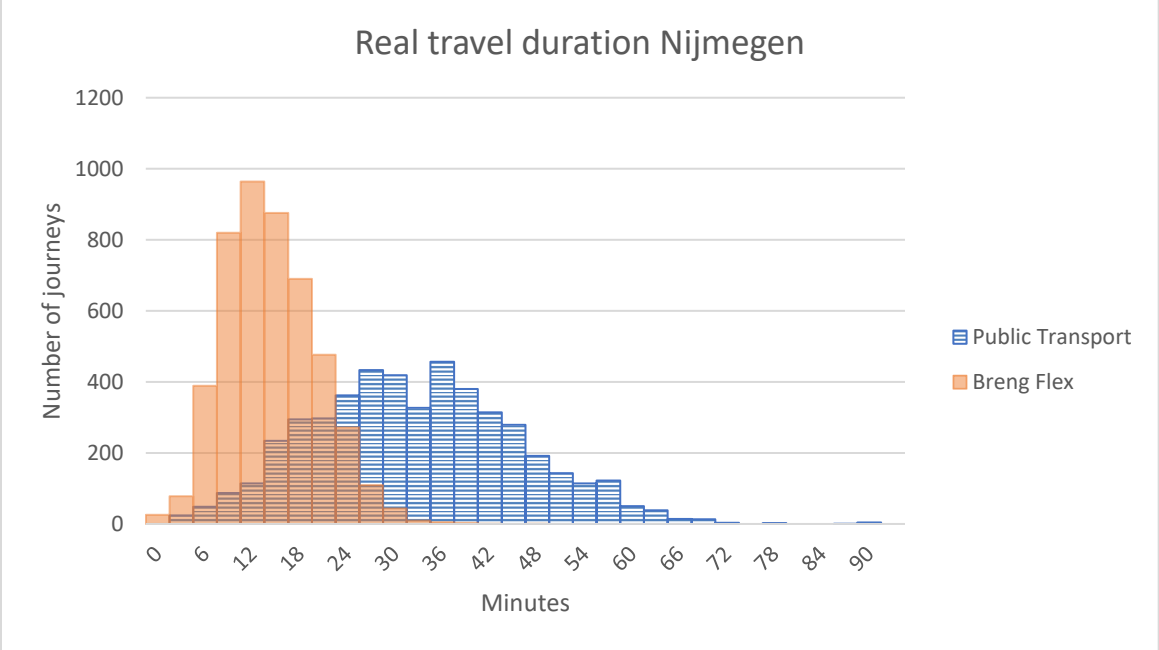

Figure G.2 Distribution of real travel durations in Nijmegen of Breng Flex and the public transport alternatives

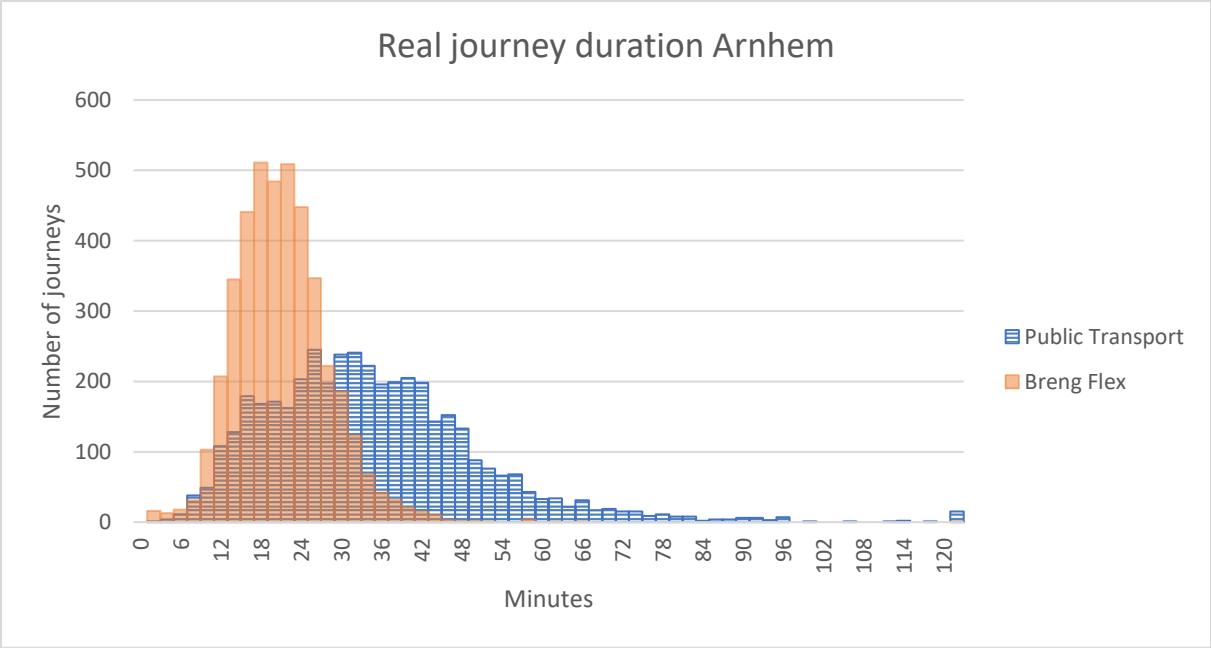

Figure G.3 Distribution of real journey duration Arnhem

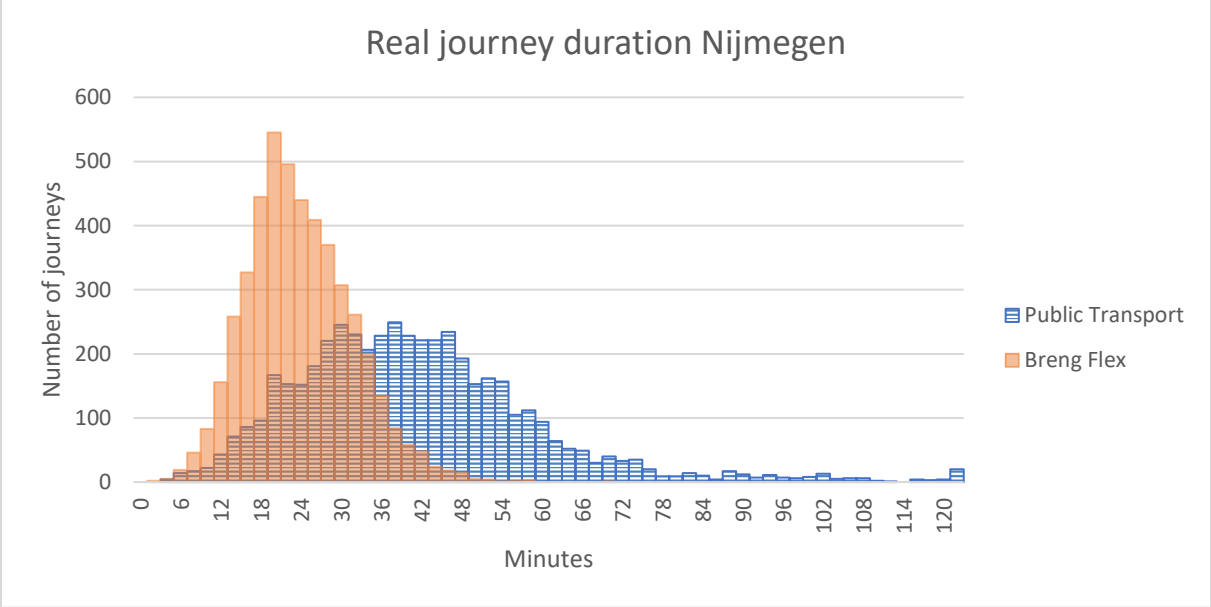

Figure G.4 Distribution of real journey duration Nijmegen

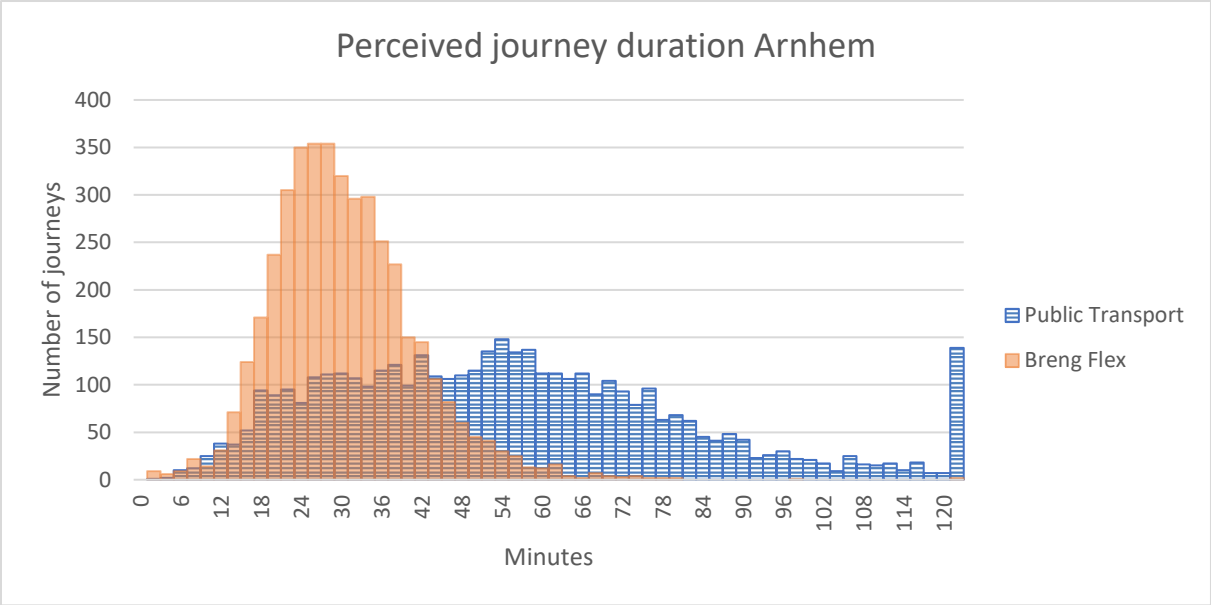

Figure G.5 Distribution of perceived journey duration in Arnhem

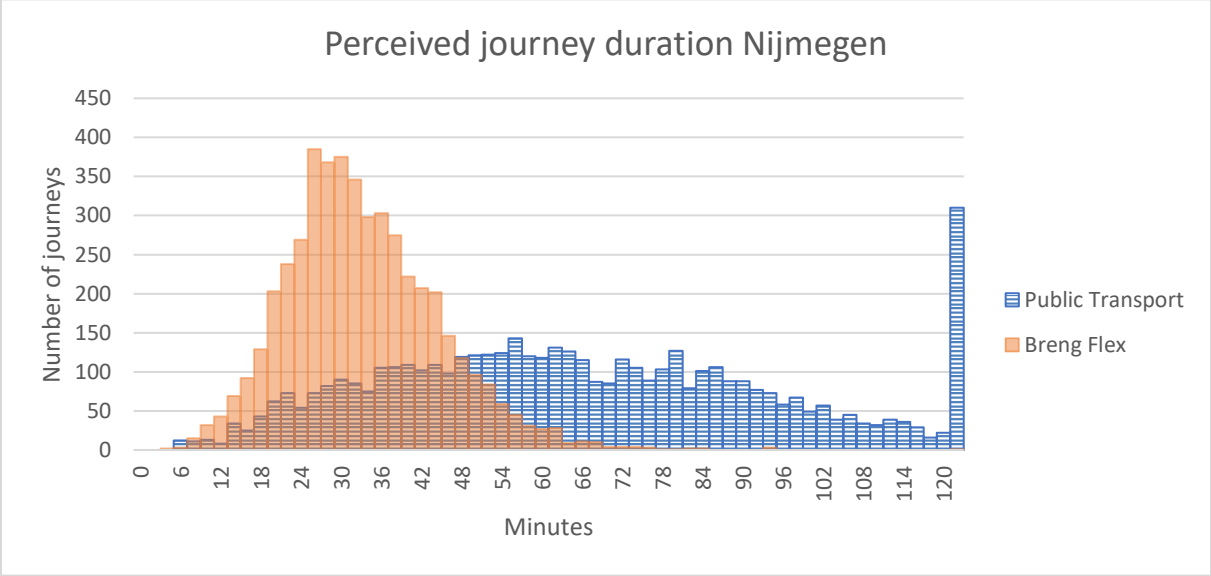

Figure G.6 Distributions of perceived journey duration in Nijmegen