UNIVERSITY OF TWENTE.

BMD Parkmanagement

Public transport for XL Businesspark

Author	W.F. (Stefan) Boersma
Studentnumber	2597683
Internal supervisor	Prof. dr. ing. K.T. (Karst) Geurs
External supervisor	M.G.H (Mark) van Mast
Organisation	BMD Parkmanagement
Submission	July 2023
Study programme	BSc. Civil Engineering

Preface

This study has been done as a bachelor thesis for the University of Twente in collaboration with BMD Parkmanagement. The aim was to find solutions that could improve the public transport accessibility of XL Businesspark in Almelo. In order to do so, factors that play a role in commute mode choice and public transport ridership were researched in the literature. Additionally, interviews were done with relevant stakeholders to collect information about the specific case of XL Businesspark. These were followed by a postal code analysis to gain information about the locations where employees live. Information from these sources was used for the design of alternatives to improve the public transport accessibility of the area. In the end, a multi-actor multi-criteria analysis was performed to compare the alternatives while doing justice to the criteria of all stakeholders.

I want to thank everyone who has helped with the execution of this bachelor thesis. Special thanks to Professor Karst Geurs from the University of Twente and park manager Mark van Mast from BMD Parkmanagement for supervising me during this process. Furthermore, I want to thank Overijssel Onderweg, province of Overijssel, municipality of Almelo and Arriva for their interest and contributions to this project. Next, I want to thank OV-Oost and the companies at XL Businesspark for their data and information and finally, I would like to thank NovelT for connecting me with BMD Parkmanagement.

Stefan Boersma
Enschede, July 2023

Summary

XL Businesspark is an area south of the city of Almelo. The area is well accessible for cargo and people who come to the area by car, but misses good public transport accessibility. The area currently has one bus stop at the Pastoor Ossestraat. For some companies, this means that the closest bus stop is 2,5 kilometers away. The approach for this bachelor thesis was to get a better understanding of the travel patterns and accessibility problems at XL Businesspark. Next, these insights were used to design alternatives that could improve public transport accessibility in the area. During this study, stakeholders have been interviewed about the situation at XL Businesspark and their criteria for good public transport. These criteria were used to evaluate the alternatives that were designed to improve the accessibility of XL Businesspark.

This research started with a literature study, during which was found that travel time, travel costs, the number of transfers and walking distances play an important role in the decision whether to travel by public transport or not. To be more precise, it was found that when the travel time of public transport is more than 1,5 times longer than the travel time by car, only people who depend on public transport will remain using it [1]. For the number of transfers was found that a single transfer makes a large difference in the share of people who decide to travel by public transport. This share decreases even further when two or more transfers are required to reach a destination [10]. In a study on walking distances to public transport [4] was found that a distance of 200-500 meters is considered acceptable by almost everybody but this percentage decreases rapidly when distances become larger than 900 meters.

Other interesting results from the literature study were a number of measures that employers can take to stimulate their employees to travel by other transport modes than cars. The most effective measures were an emergency ride-home service and a matching service for employees who would like to start carpooling. Additionally, employers can stimulate employees to use other modes by providing higher travel allowances for some modes of transport or a public transport card from the company. Finally, companies can adjust their working hours to match better with the public transport timetables.

The literature study was followed by an analysis of the postal codes of employees from three companies. The analysis was done with a dataset of 462 postal codes, which is a significant amount, considering that the total number of employees at XL Businesspark varies between 1000 and 2000 people throughout the year. The analysis showed that 22% of the employees come from Almelo and another 24% from Enschede. These cities are followed by Hengelo and Oldenzaal with shares of 11% and 5% respectively. A common characteristic of all these cities is that they have a relatively high address density and low average socioeconomic status compared to the rest of Twente.

Interviews with HR managers from companies at XL Businesspark revealed that some companies work only during the day and others in two shifts. Other interesting things that the interviews showed is that the share of employees that cycle to work is similar to the average in the Netherlands, but that the percentage of people who travel by car is higher because hardly anyone commutes by public transport.

An analysis of the accessibility by bicycle, car and public transport showed why public transport is such

an unattractive mode of transport for most people. The travel time ratio of 1,5 that was found during the literature study is exceeded in almost the entire Twente region. Especially when the walking times to the nearest stop are included. These travel times increase even more for workers whose shift starts early in the morning or ends late in the evening because during those hours public transport is limited or not available at all.

Next, three alternative bus line configurations and an example of a shuttle bus line were designed. The bus line alternatives all provide a 600-meter shorter walking distance from the west side of XL Businesspark to the nearest bus stop. This comes however at the cost of skipping current bus stops or increasing the chance of passengers missing their transfer at Almelo Centraal or train station Delden. A shuttle bus could be an interesting option because it removes the disutility of transferring to another line. At the same time, this option reduces the walking distance and benefits from the same highway connection as car commuters do. Therefore this is the only option that enables employees to reach their destination within 1,5 times the travel time that it would take them by car.

The shuttle bus is also the most attractive option for most stakeholders according to the multi-actor multi-criteria analysis. During this part of the research project, a multi-criteria analysis was performed for the province of Overijssel, the municipality of Almelo, public transport company Arriva, companies at XL Businesspark and employees who work at these companies. Each of these MCA's was performed with criteria and weights that were derived from interviews with the stakeholders. An exception to this are the employees, whose criteria were retrieved from literature because these were expected to be more representative of the entire group of employees. The only group of stakeholders for which a shuttle bus is not the most attractive option are the companies at XL Businesspark because it is the only alternative that is expected to require an investment from their side.

Suggestions for further research are a more detailed analysis of the working hours of companies and locations where employees live. This could give more information about the actual demand for a shuttle bus. Besides that, it may show that the demand can be increased by slightly adjusting the working hours of some companies. Another topic that could be further investigated is a flexible, demand-driven public transport solution for people within Almelo. This could be interesting because many employees come from Almelo, but that does not mean that necessarily everybody cycles to work. Especially on such short distances, the walking distances and transfer times can make public transport unattractive.

Finally, a few recommendations are done to increase the attractiveness of the existing bus stop at the Pastoor Ossestraat. This bus stop currently does not have a platform, rain shelter or bicycle storage, which makes it unattractive to use. Adding these facilities and transforming the bus stop into a mobility hub for shared e-bikes and e-scooters could potentially improve the user experience and increase public transport demand. Besides that, mobility hubs on XL Businesspark could potentially decrease the travel time between the bus stop and the company where someone needs to be. Another recommended way to improve the user experience of the bus stop is the addition of a pedestrian path between the Pastoor Ossestraat and the west side of XL Businesspark, which would shorten the walking distance to the west side of XL Businesspark.

Contents

List of Figures

List of Tables

1 Introduction

1.1 Background

The XL Businesspark is an industrial area located in the city of Almelo. Like many other industrial areas in the Netherlands, it is located at the edge of the city to provide easy access to major roads and avoid hindrance to the citizens.
Besides roads for cars, the area also features separated bicycle lanes along most of its roads, which allows people to travel by bike or on foot in a safe and comfortable way. However, despite these good connections for cars and bicycles, the area is not well served by all transport modes. The only access to public transport that people at the business park have, is a single bus stop in both directions of the Pastoor Ossestraat, which is a road that crosses the area from north to south. This is not a lot for an area of 120 HA. For some companies, it means that the nearest bus stop is 2,3 kilometers away.

The limited access to public transport is a problem for companies at the XL Businesspark because a significant portion of the employees are blue-collar workers, who fulfill, low-paying jobs. Those people can not always afford to own a car. This means that the companies try to attract employees who can not always access the area in a reasonable way.

In this research, a solution will be searched for this problem by designing and evaluating potential public transport solutions that could increase the accessibility of the XL Businesspark for potential employees.

1.2 Problem description

The challenge at business parks is that it is hard to make public transport in these areas financially viable. They are often located at the edge of cities, far from the city center where most public transport is located. These long distances result in long travel times, which makes public transport often an unattractive option. Unusual working hours and an unbalanced demand, causing empty vehicles half of the time, add to the challenge of providing public transport that suites the needs of business parks.

1.3 Objective & research questions

In order to find a solution that can solve the problem at the XL Businesspark, an objective and research questions have been formulated. Some concepts are elaborated on below the objective.

Research objective

The research objective of this study is to examine current *commuting patterns* and *public transport accessibility* for *blue collar workers* at XL Businesspark in Almelo, and how relevant stakeholders evaluate options to improve *public transport accessibility*.

Concepts

Commuting patterns: In the scope of this research, travel patterns consist of the location where people live and the time at which they travel between home and the XL Businesspark.

Public transport (PT): In the context of this research project, public transport refers to a means of transportation where passengers do not own the vehicle they are traveling with and may share a vehicle with other passengers during their trip.
Accessibility: In this study, accessibility refers to the distance to public transport, commute distance, travel time and travel costs for (potential) blue-collar workers at XL Businesspark.
Blue collar workers: Blue collar workers are people with jobs that require manual labor and a practical education background. Blue-collar workers often receive relatively low salaries.

Research questions

1. How accessible is XL Businesspark and what do the current travel patterns of blue-collar workers at XL Businesspark look like?
2. How can the accessibility of XL Businesspark be improved by modifying bus lines and implementing flexible public transport?
3. How do the alternatives compare to each other according to relevant stakeholders?

1.4 Outline of the thesis

In Chapter 2 are the results from the literature study discussed. These are followed by an explanation of the methodology in Chapter 3, after which the three questions are answered in Chapters 4, 5 and 6. This report ends with a discussion of the results and limitations in Chapter 7, conclusion and recommendations in Chapter 8 and suggestions for further research in Chapter 9.

2 Literature Study

To improve the public transport accessibility of XL Businesspark, it needs to be known what accessibility exactly means and how it can be influenced. In this chapter, a literature study is performed on these topics. In Section 2.1 is accessibility defined and conceptualized. This is followed by Section 2.2, which focuses on commute mode choice factors that can be influenced by a public transport intervention. Thirdly, the role of the relevant stakeholders and a framework to compare their opinions are studied in Section 2.3.

2.1 Definition of accessibility

Accessibility is a complex concept with many things that influence it. Geurs and Van Wee [6] define accessibility as "the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s)". In their paper, accessibility is conceptualized with four components:

- Land-use component (supply of and demand for the utilities available at a location)
- Transport component (disutility of covering the distance between origin and destination)
- Temporal component (temporal constraints to participate in activities)
- Individual component (needs, abilities and opportunities of individuals)

Since the aim of this research is to improve the accessibility of the XL Businesspark for (potential) employees by means of better public transport, the focus lies on improving the transport and temporal component, while taking into account the individual component.

2.2 Commute mode choice factors

Liu et al. [9] and Ha et al. [8] have analyzed the contribution of several variables to the commute mode choice of people. A difference between these studies is that Liu et al.[9] separate the outcomes by level of income. This study also found that blue-collar workers are more likely to commute by car than white-collar workers. Ha et al. [8] on the other hand included factors such as commute distance and car ownership, which were not included in [9]. Since not all of the factors that were found to play a significant role can also be influenced, a selection of the factors is further investigated. These are:

- Travel time
- Travel costs
- number of transfers
- walking distances

Besides these factors that can be influenced by public transport interventions, commute distance is taken into account as a factor to estimate the commute mode choice distribution in the current situation.

2.2.1 Commute distance

One of the topics that the Dutch Central Bureau for Statistics (CBS) investigates is personal transportation. In Figure 1, is shown how the mode share for commute trips changes with the distance. It can be seen that walking is popular for distances up to 2,5 kilometers, after which its popularity decreases drastically. Cycling is also a popular option for short commutes, especially for distances between 1,0 and 2,5 kilometers. Its mode share decreases however when distances become longer and eventually, it drops below 10% for distances that are longer than 15 kilometers. Cars and trains on the other hand, become increasingly popular when the distances increase.

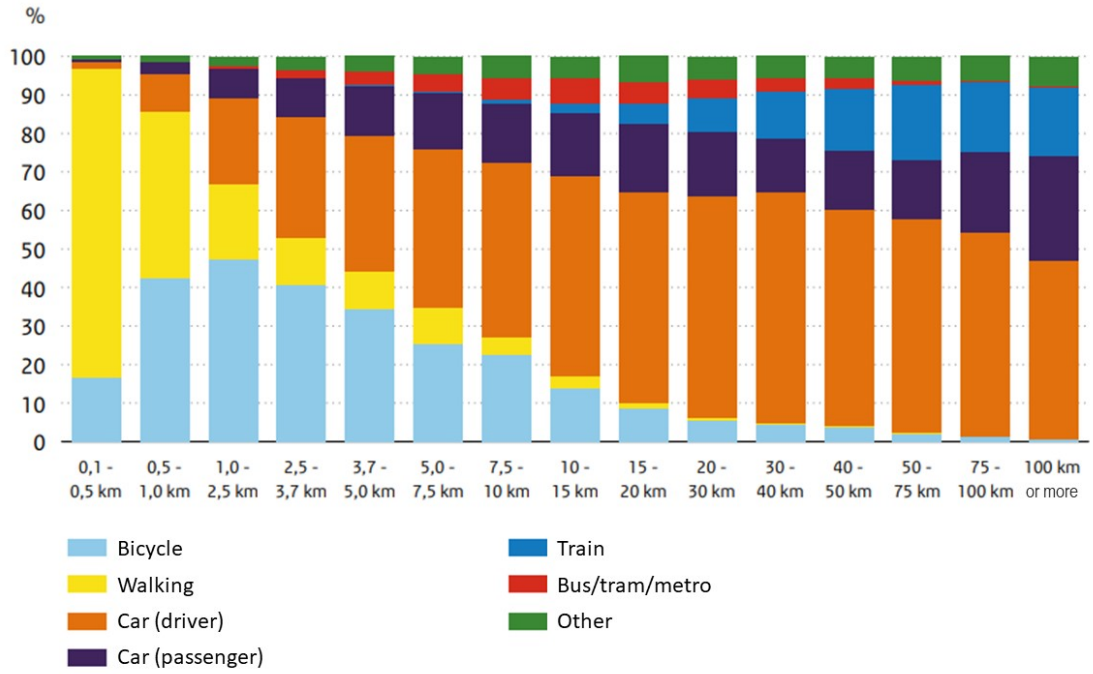

Figure 1: Mode share per distance class based on ODiN 2019 [5]

This graph shows that cycling is only considered a reasonable mode of transportation for relatively short distances. Therefore, this study will only focus on cycling accessibility for distances up to 5, 10 and 15 kilometers, which correspond to mode shares of 55%, 31% and 14% respectively [5].

The data also show that cars are the most popular mode of transport for trips longer than 5 kilometers. The second most popular mode is cycling for distances between 5-15 kilometers and public transport for distances that are longer than 15 kilometers. An important note for these numbers is that CBS does not differentiate between different types of jobs. Ha et al. [8] found in their logistic regression model that blue-collar workers have a stronger preference for car commuting than white-collar workers. Therefore the mode share distribution between cars and public transport at XL Businesspark is expected to be more car-focused than the numbers of CBS suggest.

2.2.2 Travel time

The factors that influence the travel time of a trip are not the same for all transport modes. Bicycle travel times are largely influenced by the type of bicycle and the physical condition of the cyclist. This is different for trips made by car, which are influenced by speed limits and congestion. Travel times for public transport also depend on other characteristics, since they are influenced by timetables and the locations of stops and stations.

Schleinitz et al. [15] have studied the cycling speeds of different types of bicycles. In Figure 2 can be seen how average speeds differ between people and per type of bicycle.

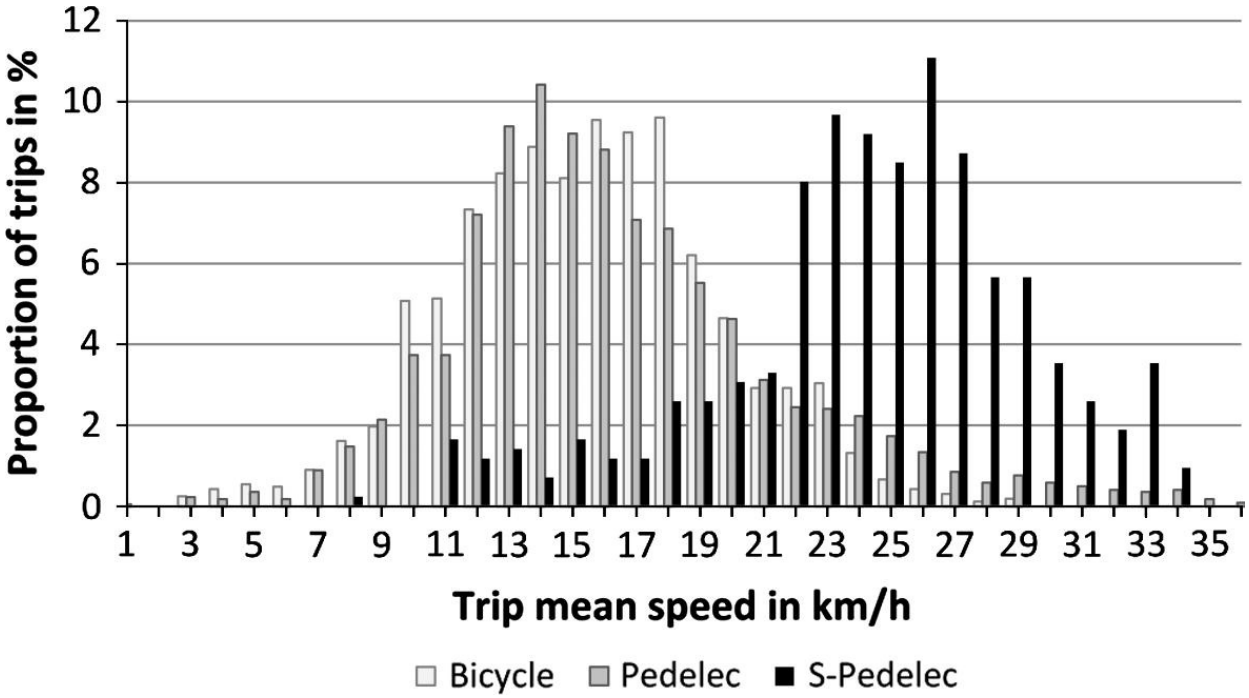

Figure 2: Cycling speed distributions for different types of bicycles [15]

In Figure 2 can be seen that there is a lot of variation between average speed. Another thing that can be seen in the figure is that speed-pedelecs are much faster than regular bikes and normal pedelecs. These two factors make it hard to predict bicycle travel times.

In Table 1 are the average travel distance and travel time shown per commute transport mode. These numbers are published by CBS and show that people who cycle to work have an average travel time of 19 minutes.

Table 1: Average travel distance and time per trip per transport mode [2]

Commuting	Avg. travel distance per trip (km)				Avg. travel time per trip (min)			
Transport mode	2018	2019	2020	2021	2018	2019	2020	2021
Total	19,23	19,26	16,66	16,54	29,60	29,92	26,13	25,88
Car (driver)	25,05	25,22	22,81	22,78	30,76	30,88	27,83	27,57
Car (passenger)	22,74	25,41	18,59	18,04	30,47	31,99	26,82	27,11
Train	40,75	41,16	38,40	36,66	66,75	67,07	65,66	63,61
Bus/tram/metro	15,32	15,21	14,29	14,21	42,96	42,42	43,99	44,38
Bicycle	4,74	4,85	4,43	4,43	18,99	19,34	18,65	19,27
Walking	2,47	2,91	1,79	1,50	11,89	13,97	12,21	11,19
Other	24,76	21,58	16,97	21,18	32,83	30,16	24,59	28,47

Table 1 also shows that the average travel time for bus/tram/metro is longer than the average travel time by car although the average travel distance by bus/tram/metro is shorter than the average travel distance by car.

Bakker and Zwaneveld [1] have done research on mode choice and public transport. Their report states that when public transport takes more than 1,5 times longer than traveling by car, only people who depend on public transport remain using it. Important to note is that travel purposes were not taken into account in this study.

2.2.3 Travel costs

Besides the travel time, the costs of commuting play a significant role in mode choice. This section covers the user costs that commuters pay for different modes of transportation. Some employers make use of different travel allowances for different modes of transport to stimulate public transport. This was however not the case for the interviewed companies at XL Businesspark.

Car user costs The costs for traveling by car are highly variable because they depend on the type of car, driving style and how often the car is used. Nibud, an advisory institute about finances, has published estimates of the costs of car usage, which are shown in Table 2

Table 2: Costs of car ownership and usage [12]

	Mini car	Small car	Medium car	Large car
Fixed costs (month)	€172,50	€199,00	€257,00	€337,00
Variable costs (month)	€149,00	€179,00	€239,00	€301,50
Total costs (month)	€321,50	€378,00	€496,00	€638,50
Average km (year)	8.500	10.000	12.500	13.500
Total costs / km (cents)	45	45	48	57
Variable costs / km (cents)	21	21,5	22,9	26,8

In Table 2 can be seen that the variable costs/km are estimated to be equal or just over the travel allowance of €0,21 that is proposed by the government [14].

Bus user costs The costs for traveling by bus in Twente are published in [18]. Here is stated that users have to pay €0,223 per kilometer if they pay the full price. There are also subscriptions available, which let you travel unlimited or with a discount for a fixed price per month or year.

Minibus user costs The user costs for buurtbussen and Twentsflex are published in [18]. The costs for a buurtbus, which operates like a normal bus with a volunteer driver in a smaller vehicle, are the same as a regular bus. Twentsflex makes use of a fixed price of €2,25 independent of the distance or time that a trip requires.
The independent company Noaberhopper operates minibus services from or to hubs. This service, which is only operated between 9:00 and 21:00 costs €3,00 + €0,50 per kilometer.

2.2.4 Number of transfers

Transfers between vehicles increase the dis-utility of traveling between origin and destination. Part of it is the 'unnecessary' time that it takes: time that is not used to cover the distance between origin and destination. Another part is the decreased comfort of having to pack all belongings and having to walk to a different vehicle.
Lunke et al. have performed an analysis of factors that influence the public transport share in Norway [10]. Their quantification of the effects of transfers on public transport share are shown in Figure 3 In this figure, the X-axis shows the travel time ratio compared to car travel and the y-axis shows the predicted mode share of public transport.

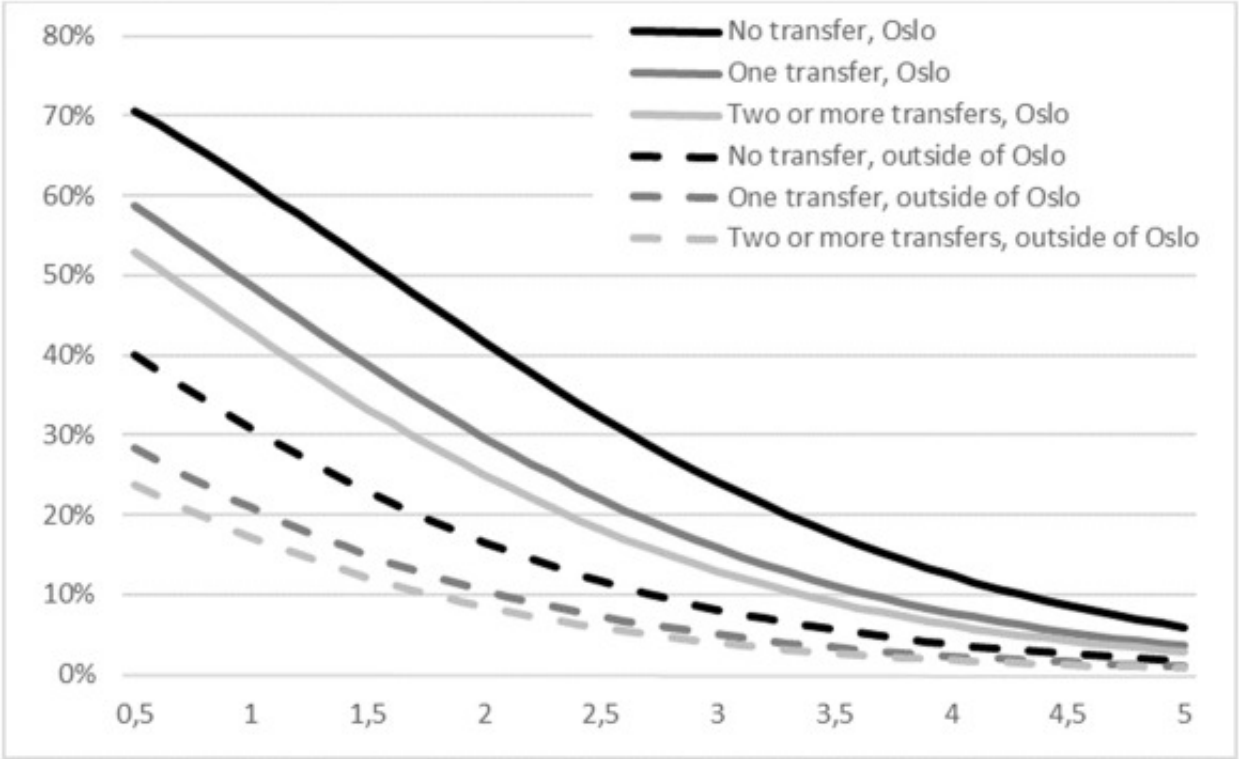

Figure 3: Effect of transfers on public transport share in Norway [10]

In Figure 3 can be seen that transferring causes a significant decrease in predicted public transport share. It can also be seen that the difference between 0 or 1 transfer is larger than the difference between 1 or 2 or more transfers.

2.2.5 Walking distances

Due to the low speeds at which walking distances are covered, the distance between an origin or destination to a bus stop can take up a significant portion of the total travel time. In 2021, CROW KpVV and Ruimte voor Lopen [4] investigated acceptable walking distances by means of a questionnaire among 489 participants. For the distances to and from bus stops, they found that 200-500 meters are generally found to be acceptable for most people. This information was based on the stated preference for walking time and the average walking speed. The average walking speed that was used in the report is 90 m/min, but it is mentioned that there is a large variety in walking speeds with speeds below 36 m/min and above 132 m/min for the slowest and fastest people respectively. The results from the questionnaire are shown in Table 3

Table 3: Acceptable walking distances to and from bus stops [4]

Walking time	Distance (90 m/min)	Responses (%)	Responses (cum. %)
Max 0-2 min	0 - 180 m	3%	100%
Max 2-5 min	180 - 450 m	27%	97%
Max 5-10 min	450 - 900 m	48%	70%
Max 10-15 min	900 - 1350 m	17%	22%
Max 15-20 min	1350 - 1800 m	4%	5%
Max 20-30 min	1800 - 2700 m	1%	1%
Over 30 min	>2700 m	0%	0%

Based on these results, the researchers propose an acceptable walking distance of 200-500 m, a distance which is acceptable for approximately 97% of the respondents.

In conclusion, attractive public transport takes at most 1,5 times longer than traveling by car, costs less than traveling by car, requires few transfers and stops within 500 meters of the destination.

2.3 Roles and inclusion of relevant stakeholders

Stakeholders play an important role in the implementation of public transport. Gommers and Wortman [7] emphasize that stakeholder collaboration is especially important for public transport to business parks, because the characteristics of the demand require a different approach than most other public transport lines. The stakeholders who are relevant for the implementation of better public transport for XL Businesspark are:

- Province of Overijssel
- Municipality of Almelo
- Public transport company Arriva
- Companies at XL Businesspark
- Employees at XL Businesspark

Public transport is the responsibility of the province, which makes agreements with public transport companies such as Arriva to provide the service. According to a policymaker from the province of Overijssel, they also pay half of the public transport costs via subsidies. Bakker and Zwaneveld [1] mention the same percentage for train costs and an even higher percentage of almost 75% for bus/tram/metro costs. The municipality, companies and employees are not responsible for public transport but are stakeholders because they are influenced by the effects of public transport on accessibility and attractiveness. In Section 2.3.1 is the role of employers further investigated and in Section 2.3.2 is described why a multi-actor multi-criteria analysis is used to evaluate the public transport alternatives for XL Businesspark.

2.3.1 Role of employers

Employers can fulfill a special role in the organization of a public transport service for XL Businesspark because they have a direct connection with the employees. The role of employers in mode choice is more in-depth investigated by Vanoutrivespi et al. [19]. In this article, an extensive overview is given of mobility management measures that can be taken by employers to discourage, so-called, single occupant vehicle (SOV) commuting. The measures related to public transport and carpooling are also relevant for the case of XL Businesspark since these also indicate what employers can do to increase the demand for (flexible) public transport.

The article describes that carpooling promotion is easy and costs little, but is not always effective due to the disadvantages of carpooling compared to solo commuting by car. Options to make it more attractive are an emergency ride home service and a matching service to help employees find a carpool partner.

Other options to stimulate alternative transport modes are travel information and travel allowances. Employers can for example choose to offer higher travel allowances to employees who travel by bicycle or public transport. Providing the employees with a public transport ticket which is paid for by the company can also reduce car usage because it removes the boundary of finding the cheapest subscription.

Additionally, the article mentions how alternative working schedules can impact the demand for alternative transport modes. Flexible work schedules can for example provide employees with better public transport connections, but it can also make it harder to organise carpooling. Another option is a compressed working week, which means that employees work the same amount of hours in fewer working days and therefore have to travel less often between work and home.

From next year, companies with 100 or more employees also need to report how and how much their employees travel. This measure provides the government with more information and can make employers more aware of their influence on the travel behaviour of their employees.

2.3.2 Multi-actor multi-criteria analysis

In order to ensure good collaboration between the actors that play a role in the case of XL Businesspark, all stakeholders need to feel represented and involved in the evaluation of the alternatives. This is done with a multi-actor multi-criteria analysis (MAMCA), which is a method explained in an article by Macharis et al. [11]. The benefit of this method, compared to a normal multi-criteria analysis (MCA), is that the different stakeholders can all have their own criteria and weights. These are used to perform an MCA for each stakeholder. The results from these analyses show for each stakeholder which solution they prefer and why. This gives the decision-makers a better understanding of the situation and allows them to make a well-informed decision. The chance of successful implementation also increases with this method, since stakeholders who are involved and feel represented are more likely to accept a solution that may not be to their advantage.

3 Research Methodology

In order to answer the research questions that have been formulated for this study, several research methods were needed, which are described below.

3.1 Current accessibility and travel patterns

The current accessibility and travel patterns were analyzed by means of interviews with HR managers from companies at XL Businesspark. All companies at the business park were also asked to share the postal codes of their employees for the accessibility analysis. Eventually, three companies provided those.

Where do they live?
To get an idea of the locations where employees live, the postal codes are plotted in ArcGIS and compared with spatial data from the Central Bureau for Statistics on socioeconomic status and address density
At what times do they commute?
During the interviews with the HR managers are asked at which time the working days start and end and how much flexibility there is in these working hours. This gives a clear overview of the arrival and departure times at XL Businesspark.
What is their current mode of transportation for commuting?
During the interview was asked what modes of transportation the employees use and which type of travel allowance they receive. All three companies used a travel allowance which is independent of the mode of transportation, so exact numbers were not available. Therefore, the HR managers gave estimates of the distribution of travel modes based on their knowledge of the employees and based on the parking lots.
How accessible is XL Businesspark in the current situation?
In order to determine the current accessibility of the business park, a comparison is made between the travel times by car and public transport at the arrival and departure times that are found in the interviews with the HR managers. To determine the accessibility by car, a network analysis is performed in ArcGIS, which generates accessibility isochrones that show which areas can be reached within a certain amount of time. The accessibility by public transport is determined with a travel time API demo [16] and an investigation of the bus stops and train stations that are accessible from XL Businesspark with one transfer or less. Both investigations are performed for several different departure and arrival times.

3.2 Accessibility of XL Businesspark

What are the requirements and limitations for the alternatives?
A list of requirements and limitations for the alternatives is largely derived from literature on factors that play a role in mode choice. Additionally, requirements that were suggested by public transport experts from the Province of Overijssel, Keolis and Arriva were taken into account.
Which alternatives could there be implemented?
For the modifications that can be done to bus lines is investigated what the routes and timetables of the current lines look like. Together with data on how often different bus stops are used and how many

people travel with certain lines, this information provides inspiration for new bus line configurations. The realistic options are further developed into a number of alternatives that exist of a combination of new line configurations. The flexible public transport options are derived based on the locations where employees live and the allowable travel time to reach those locations.

What impact would the alternatives have on the accessibility of XL Businesspark?

The accessibility improvements that the alternatives provide to XL Businesspark are analyzed by looking at the changes in travel time and the number of people that can access XL Businesspark within a reasonable amount of travel time.

What would be the costs and benefits of the alternatives?

The costs and benefits of the alternatives are estimated using guidelines for the costs of public transport. Besides these cost estimations, it is investigated how many passengers would need to use the alternative bus line configurations and what the ticket price of a shuttle bus would need to be.

3.3 Multi-Actor Multi-Criteria Analysis

For the comparison between the alternatives, a multi-actor multi-criteria analysis is used. This is a method developed by Macharis et al. [11] to make sure that all stakeholders are taken into account. The difference with a regular MCA is that for this method, an MCA is performed for each stakeholder individually. This gives a more in-depth overview of all the stakeholder opinions on all the alternatives.

Which criteria do the stakeholders have?

Most of the stakeholder criteria are derived from meetings during which is asked or talked about the criteria that play a role for the stakeholder. The criteria for employees are not retrieved from interviews but follow from the mode choice factors discussed in the literature study.

Which weights do the stakeholders give the criteria?

The weights are assigned based on the relative importance that the criteria have according to the people that were interviewed. Not all weights were quantified during the interviews. In those cases, the quantification was done based on the qualification that the interviewees gave. The weights for employees are taken from the same literature source as the criteria.

What is the best alternative for each stakeholder?

The multi-criteria analyses for the different stakeholders are performed by giving each alternative a score between 1-5 on all criteria. The scores and weights together lead to a grade between 1-5 from each stakeholder for each alternative. The grades of the different alternatives are compared in a graphical representation to give an overview of the stakeholder opinions on the alternatives.

4 Travel Patterns of employees

The methodology to answer the question 'What do the travel patterns of blue-collar workers at XL Businesspark look like?' has already been described in Chapter 3.1. In this chapter, the subquestions are answered, leading to the answer to the research question.

4.1 Where do the employees live?

Three companies have shared the postal codes of their employees. Due to privacy reasons, these are only shared as graphical representations in PC4 and PC5 format. This means that respectively only the first four or five characters of the postal code are taken into account. For the same reason, only the approximate location of the companies is shared, instead of their names.

4.1.1 Locations where employees live

Figure 4 shows the XL Businesspark divided into three zones. Zone 1 is the west side, containing the area from the harbour up until the highway ramp. Zone 2 is located on the other side of the ramp and ends at the Pastoor Ossestraat. The third zone is the area east of the Pastoor Ossestraat.

Figure 4: Zone distribution of XL Businesspark

In total, the three companies, which are located in zones 1 and 3, provided 462 postal codes. This is a significant portion of the total number of employees at XL Businesspark. According to BMD

Parkmanagement, the number of employees varies during the year between 1000 to 2000 employees depending on the season. This means that the database of postal codes represents approximately 25-45% of the employees at the business park. Some of the postal codes were located in Germany, which made them unusable for analysis. The exact distribution of the locations of postal codes is shown in Table 4.

Table 4: Employee postal code statistics

Company	Zone	# Postal codes	# Netherlands	# Germany
1	1	177	168	9
2	1	100	100	0
3	3	185	155	30
Total		462	423	39

Plotting these postal codes on a map shows that most of the Dutch employees live in the Twente Region, which can be seen in Figure 5, which shows the number of employees per postal code in PC4 format.

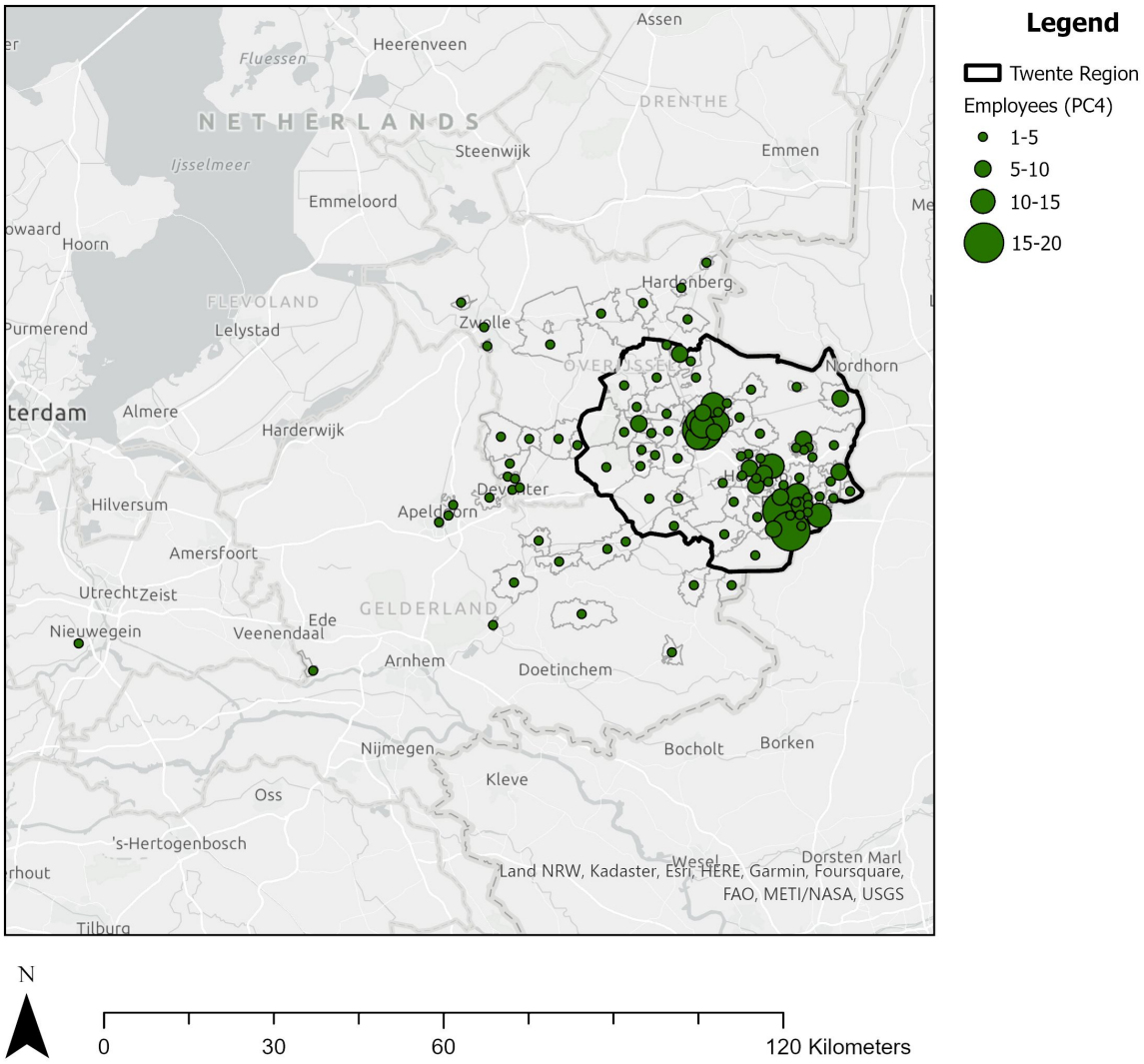

Figure 5: Postal codes of employees

Looking at the Twente region in more detail shows that most of the employees live in the four largest cities. This is shown in PC5 format in Figure 6.

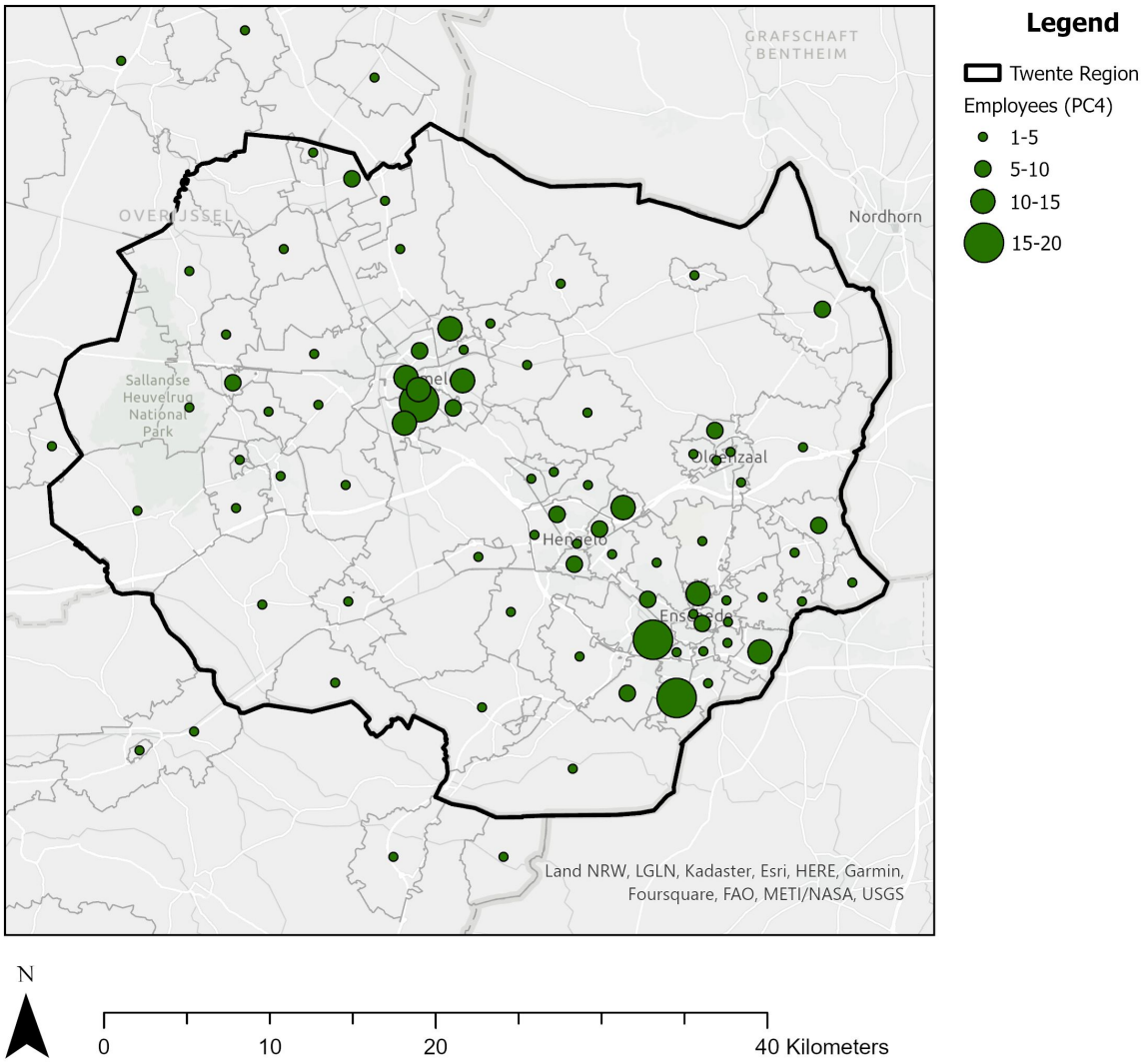

Figure 6: Postal codes of employees in Twente

A more in-depth overview of the places where employees of the interviewed companies live is given in Table 5. In this table, the cities with more than 20 employees are mentioned separately. The table shows that most workers live in Almelo and Enschede.

Table 5: Employee postal code statistics in Twente

City of origin	# Employees	% of employees from Twente	% of employees from NL	% of all employees
Almelo	103	27%	24%	22%
Enschede	111	29%	26%	24%
Hengelo	53	14%	13%	11%
Oldenzaal	22	6%	5%	5%
Other cities in Twente	97	25%	23%	21%
Dutch cities outside Twente	37		9%	8%
German cities	38			8%

4.1.2 Characteristics of locations where employees live

With the knowledge of the locations where employees live, it is also possible to search for characteristics that are typical for those locations. This is interesting, because it provides more information about the current employees, but also provides insights that can help to predict where future employees may come from. The data that has been researched for this purpose are taken from the Central Bureau for Statistics. These data are provided in the same postal code formats as the employee data, which makes them easy to compare. The characteristics that have been investigated are the address density and socioeconomic status. Socioeconomic status (SES) is a number that CBS calculates based on income, assets, education level and employment history. The number does not have a unit but can be used to compare different areas.

The first characteristic that has been investigated is the address density of the area. The CBS has categorized the postal codes into five groups ranging from less than 500 addresses per square kilometer to more than 2500 addresses per square kilometer. Figure 7 shows that Twente consists of a few larger cities, surrounded by mostly low-density rural areas and villages. Comparing this figure to Figure 6 shows that most of the employees at XL Businesspark live in the larger cities of Twente. This is unsurprising since the more people live in an area, the higher the chance that one of them works at the XL Businesspark.

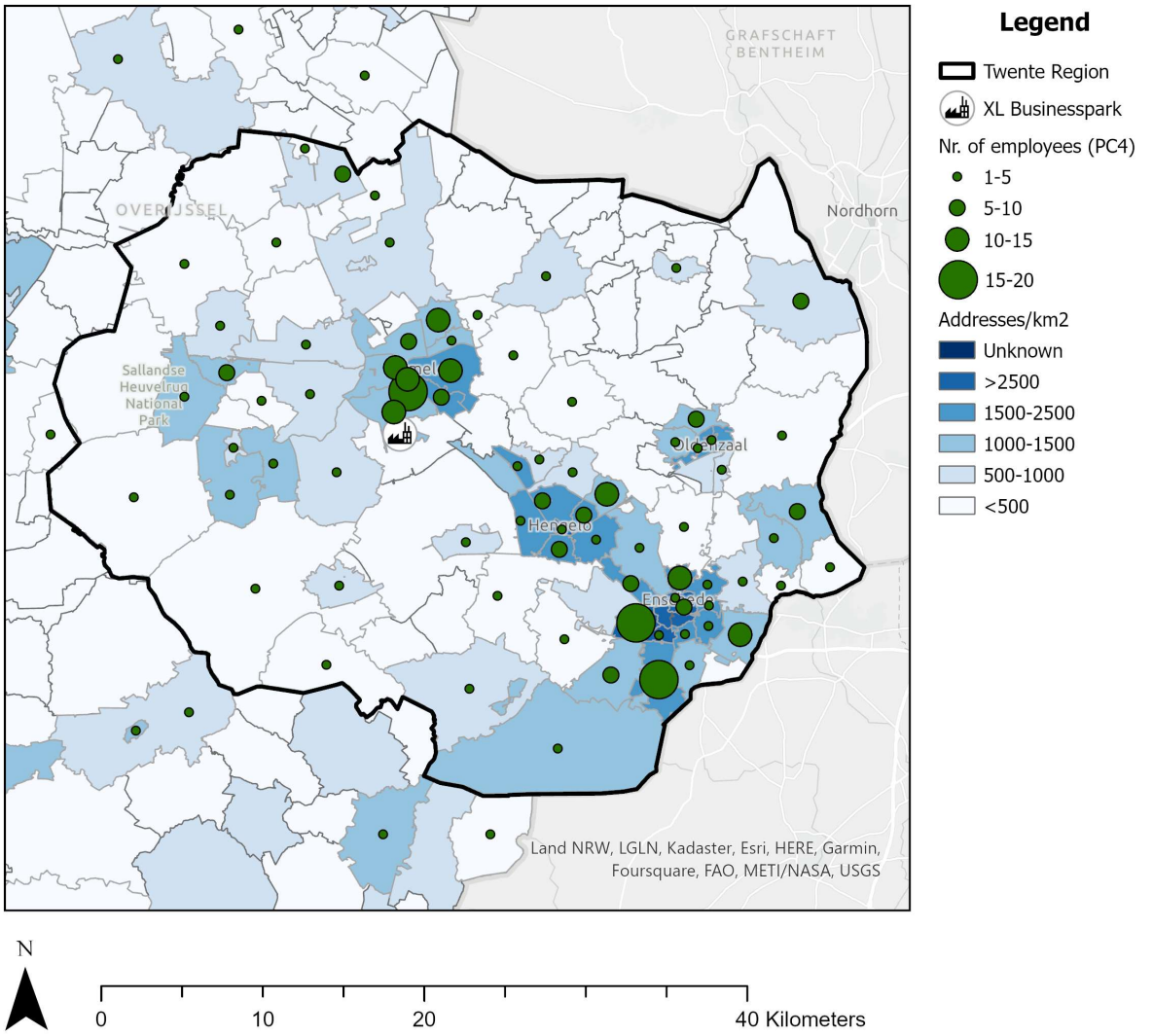

Figure 7: Address density in Twente (CBS, 2018)

The socioeconomic data in Figure 8 show that the areas where employees live are not only characterized by a high address density but also by a lower socioeconomic status compared to the rest of Twente.

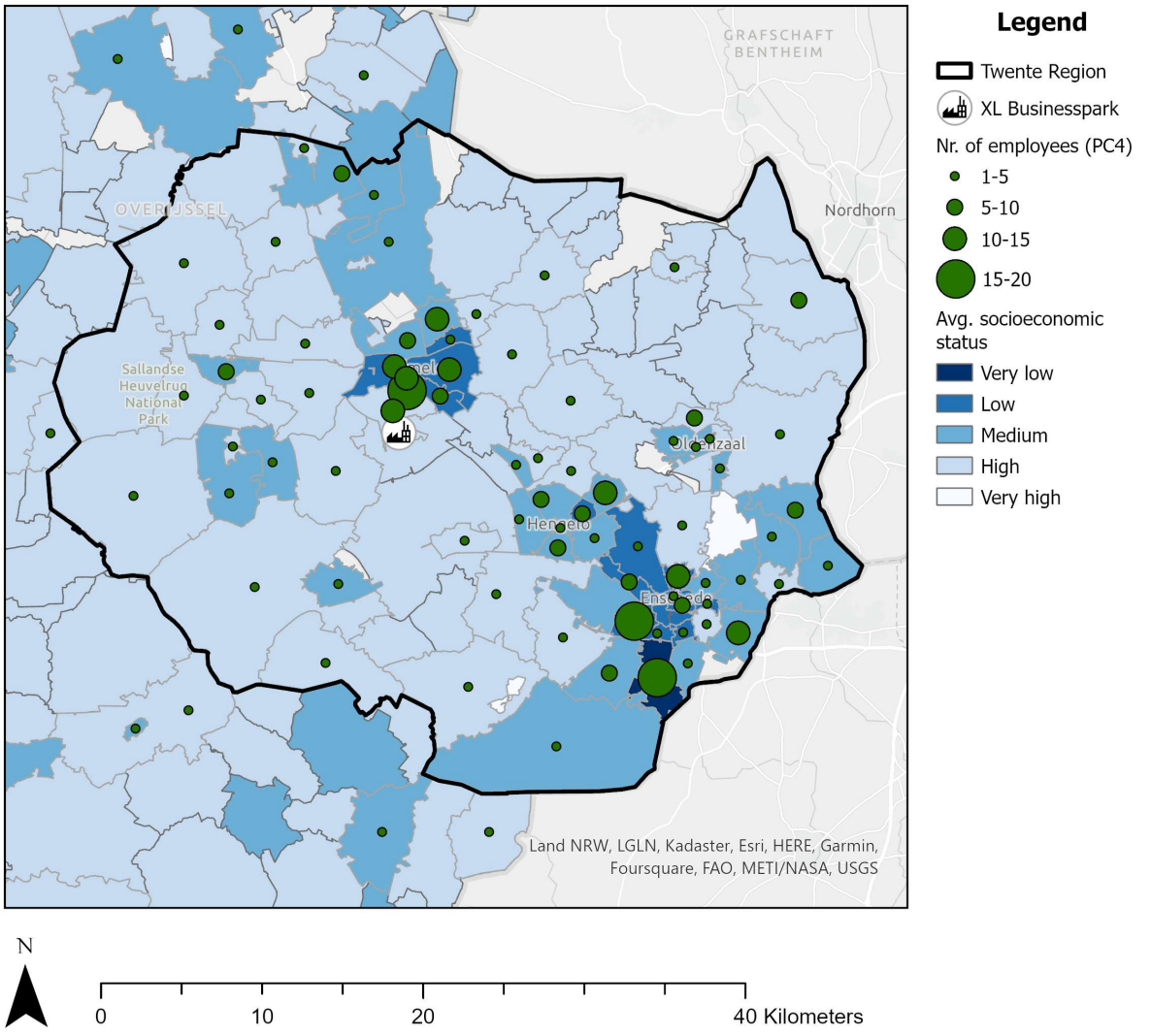

Figure 8: Socioeconomic status in Twente (CBS, 2019)

Figure 7 and Figure 8 show that the cities where most employees live have a higher address density and lower average socioeconomic status than the rest of Twente. It can however be seen that the cities Rijssen and Nijverdal also stand out from their surroundings. Therefore it is well possible that in the future new employees may also come from these cities.

4.2 At what time do the employees commute?

The three companies that were interviewed all had fixed schedules for their blue-collar workers. The office workers often had some level of flexibility in their working hours, but this group of people was significantly smaller than the group of blue-collar workers. Based on the estimates of the interviewees, the three companies have together around 400 blue-collar workers with an additional 100 in the months July, August and September.

Two of the three companies work only during the day, while the employees of the third company work

in two shifts from early in the morning till late in the evening. The exact working hours are shown in Table 6. All three companies are closed during the weekends.

Table 6: Working hours of blue collar workers at the interviewed companies

Company	Zone	Shift	Start	End
1	1	Day	07:30	16:00
2	3	Morning	06:00	15:00
		Evening	15:00	00:00
3	3	Day	07:00	16:00

4.3 What are employees' current modes of transportation for commuting?

At all three companies, cars are the most popular mode of transportation for commuting. Other popular options for people who live in or near Almelo are bicycles and scooters. Based on the estimates of the interviewees, 10-15% of the workers travel by bicycle or scooter, while public transport is used by hardly anyone. All three companies mentioned that some of their employees were carpooling. This is done either because people could not reach the area on their own, to save costs or to save parking spots. One of the companies also actively promotes carpooling by reserving the closest parking spots for those who drive together. Despite the promotion, it is not organized by the company itself. At all three companies, employees have to arrange carpooling by themselves.
All the companies have a travel allowance based on the shortest driving distance. At one company, employees only receive an allowance when they need to travel more than 10 kilometers. The amount that employees receive is a fixed amount per kilometer, independent of the mode of transportation.

4.4 How accessible is XL Businesspark in the current situation?

In this section, the current accessibility of XL Businesspark is investigated. The transport modes which are considered for this purpose are bicycle, car and public transport.

4.4.1 Accessibility by bicycle

In Section 2.2.2 was discussed how the mode shares of different transportation modes change when the commute distance increases. It was found that bicycle shares gradually decrease for commutes that are longer than 2,5 kilometers and that less than 10% of people choose to commute by bicycle when the distance is longer than 15 kilometers. In this section is analyzed how many employees are expected to commute by bicycle based on a maximum distance of 15 kilometers and the mode share percentages that are described in Section 2.2.2.

In order to take the 2,5 kilometers distance between the east and west sides of XL Businesspark into account, the cycling accessibility is analyzed for each of the three zones separately. This is done from the center of the road network in that specific zone. The locations of the road network centroids are

shown in Figure 9.

Figure 9: Centre of road network per zone

The map with the bicycle accessibility isochrones is shown in Figure 10. This map shows all the areas that are accessible within 5, 10 or 15 kilometers from one of the road centroids. Additionally, Table 7 shows an overview of the number of employees that live within 5, 10 and 15 kilometers of each zone. The accessibility isochrones for each separate zone are shown in Appendix A.

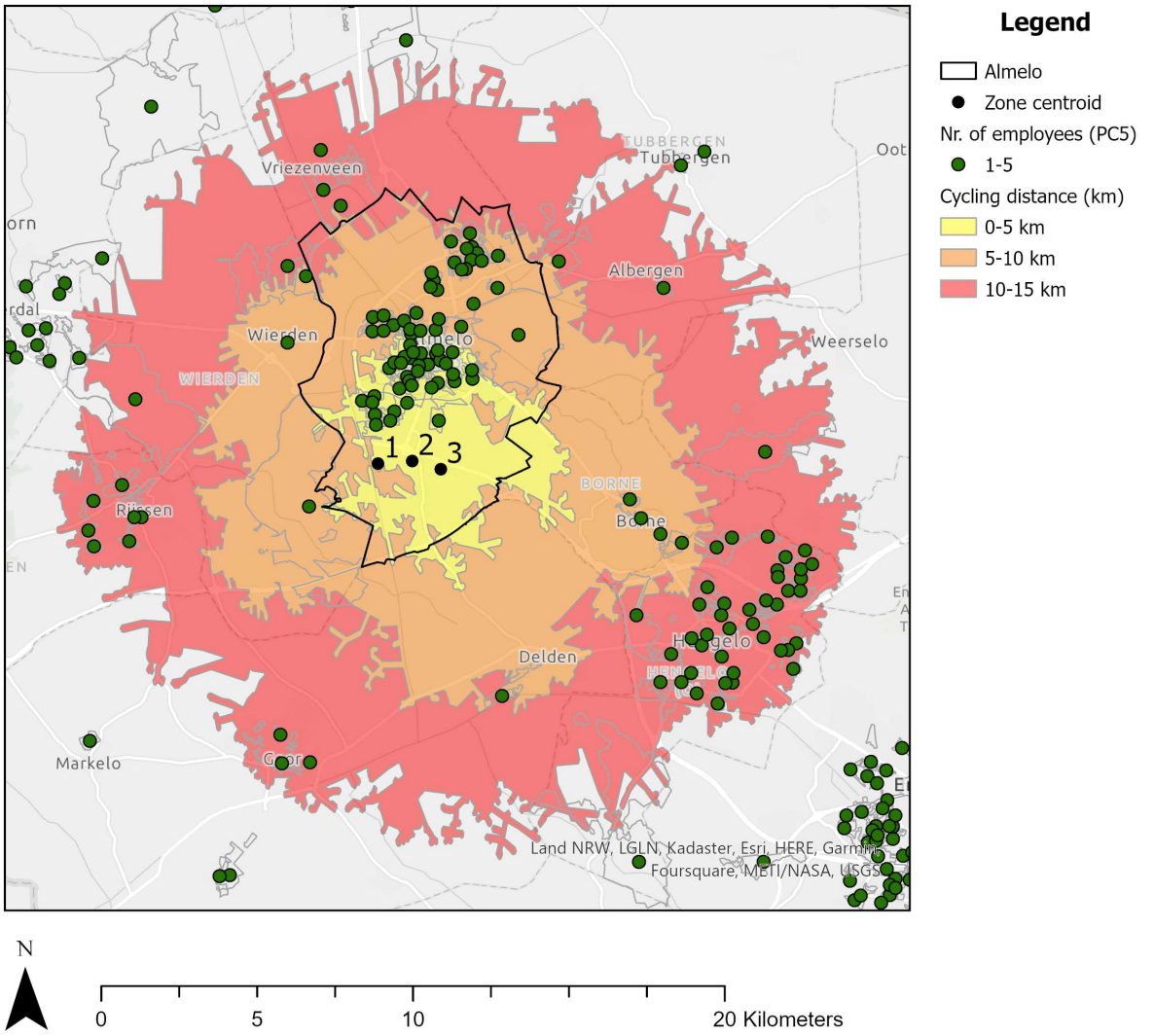

Figure 10: Cycling accessibility from XL Businesspark

Table 7: Employees within 5km cycling distance

Distance (km)	Nr. of employees within range of			
	one or more zones	zone 1	zone 2	zone 3
0-5 km	64	53	64	53
5-10 km	52	60	51	60
10-15 km	66	51	66	74

Using the bicycle shares of 55%, 31% and 14% that are mentioned by De Haas and Hamersma [5], approximately 60 of the 462 employees are expected to travel by bicycle. This is a share of 13% of all employees, which corresponds with the estimation of two of the interviewed HR managers, who said

that 20-30 of the 200 employees commute by bicycle.

4.4.2 Accessibility by car

The XL Businesspark is well accessible by car. Because the area has its own highway ramp, even the edges of the area are reachable within three minutes from the A35 highway. In Figure 11 and Figure 12 are accessibility isochrones shown of the areas that can reach or be reached from XL Businesspark within 10, 20, 30 and 40 minutes in situations without congestion.

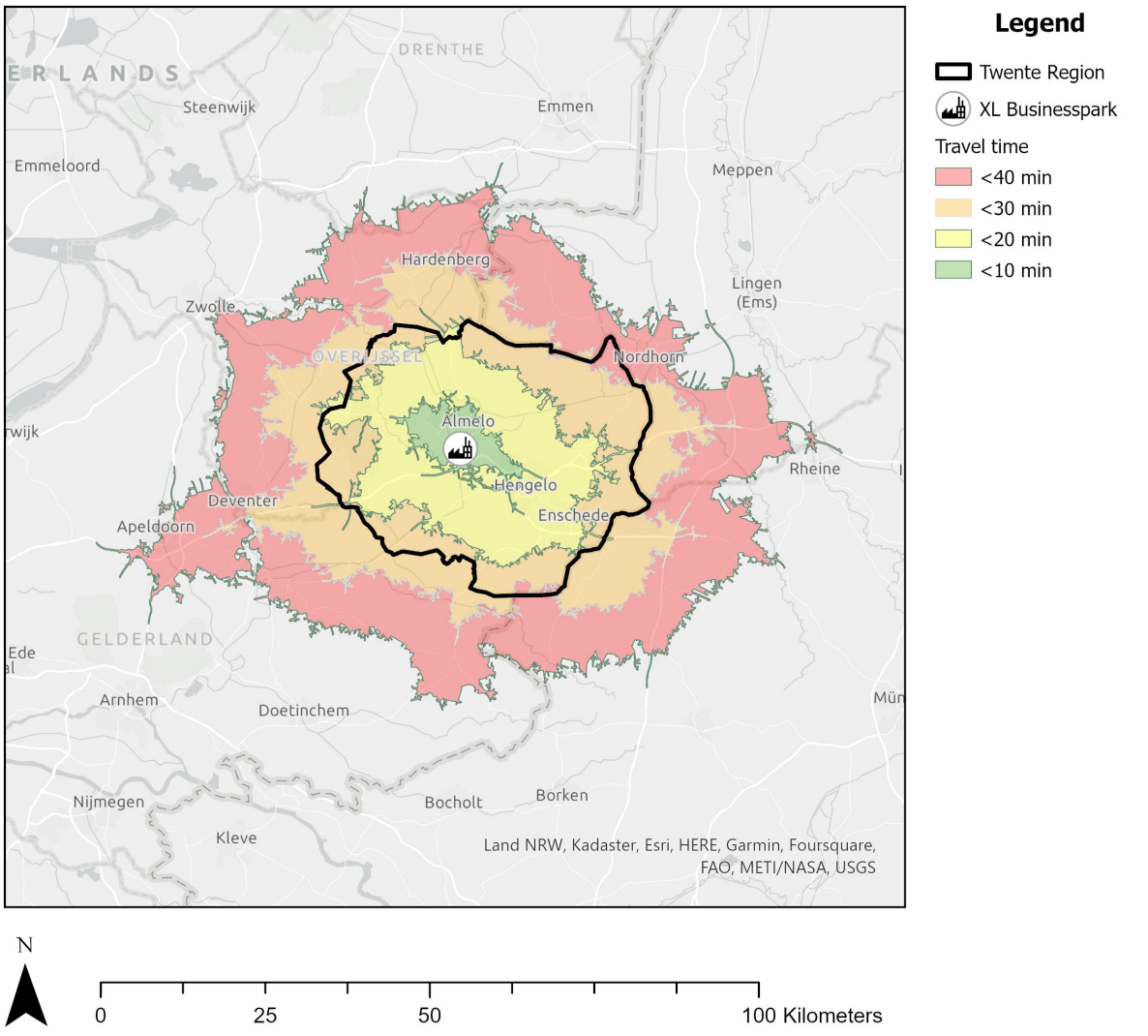

Figure 11: Travel time to the XL Park by car

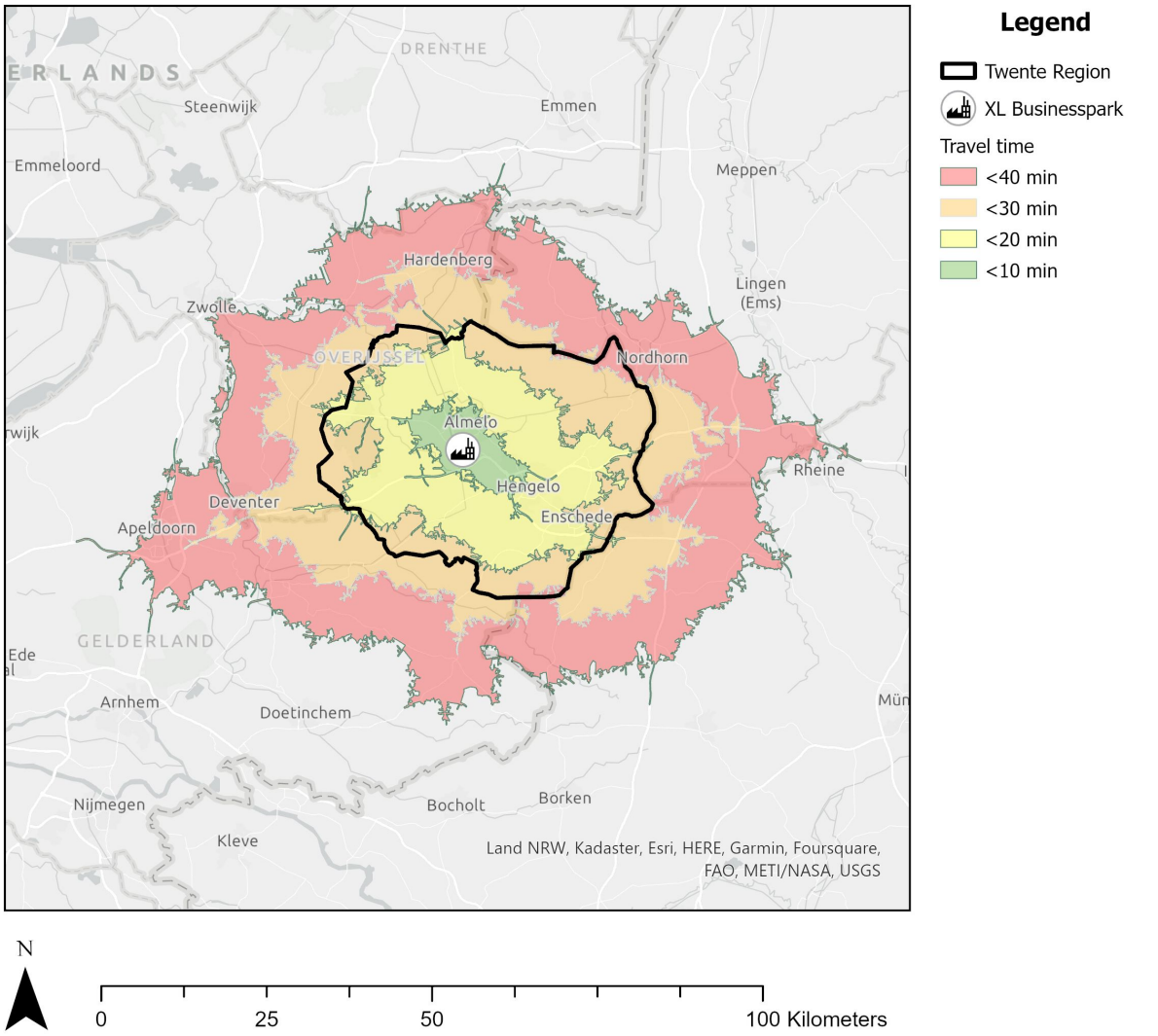

Figure 12: Travel time from the XL Park by car

The isochrones for traveling to and from the business park are almost identical with a few exceptions where it takes more time to travel to the business park than it takes to reach the location from the business park.

In Figure 13 are the postal codes of employees shown on top of the travel time by car. It can be seen that most of the employees live within or just over 20 minutes from XL Businesspark. In this figure, it can also be observed that the majority of Almelo is accessible within 10 minutes by car. The other large cities in the region are all accessible within 20 minutes or at the edge of the 20-minute service area. This suggests that employees at XL Businesspark who travel by car do not want to travel longer than approximately 25 minutes, which is a little shorter than the average travel time for commutes that was found by the Central Bureau for Statistics. The average commute travel time by car that the CBS found is 30 minutes, as can be seen in Table 1. The fact that the accessibility analysis of XL

Businesspark does not include congestion could explain part of the difference in travel time.

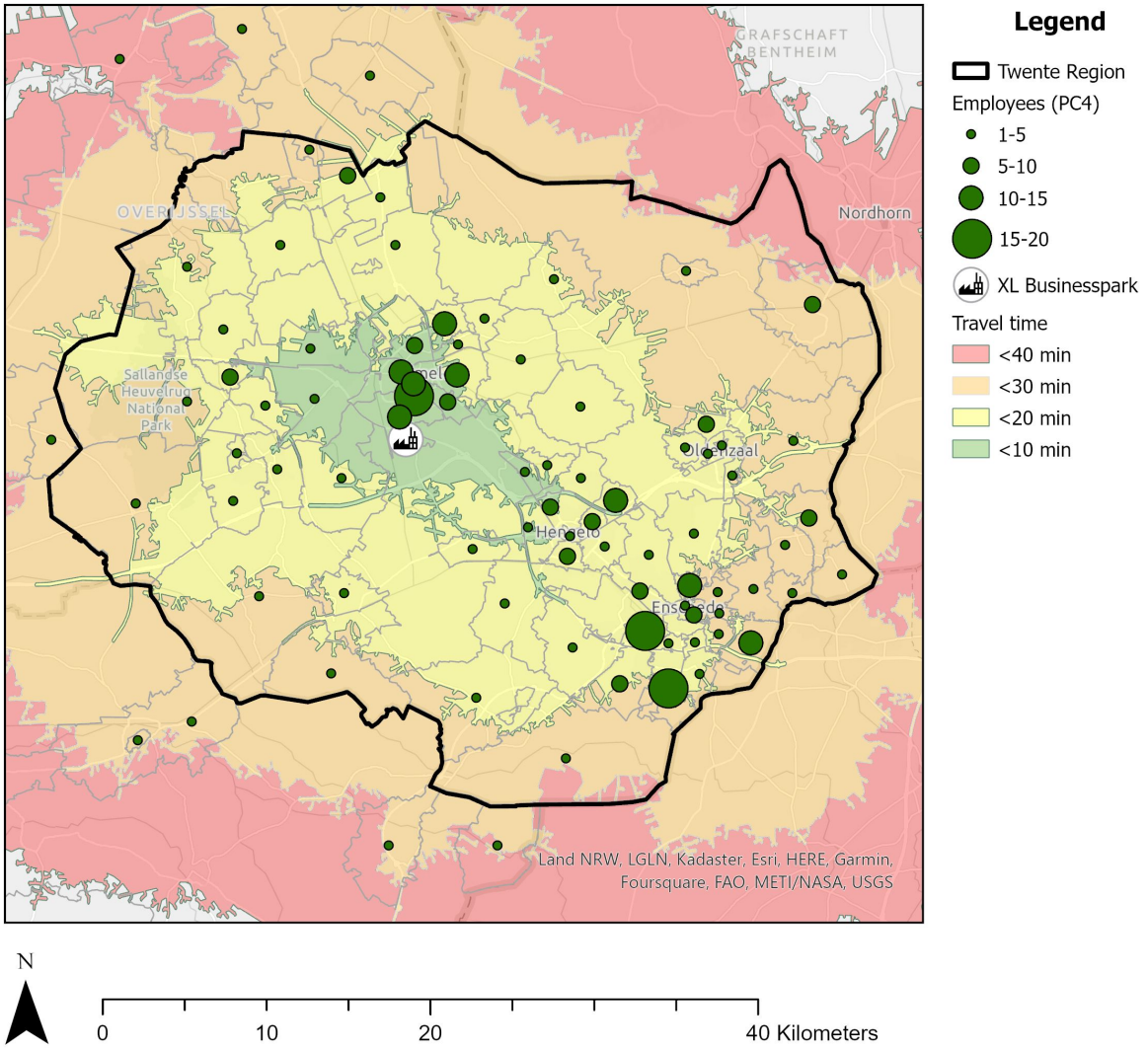

Figure 13: Postal codes of employees in relation to travel time

4.4.3 Accessibility by public transport

Based on the interviews with HR managers and data on the bus stop usage hardly any employees travel to the XL Businesspark by public transport. This is unsurprising when the travel time isochrones in Appendix B are compared with Figure 6. The isochrones show which area can be reached within 45 minutes, which is the average travel time by bus in the Netherlands, as discussed in Section 2.2.2. Considering the maximum travel time ratio of 1,5, which is explained in Section 2.2.2, it should also be the time in which almost all employees in Twente should be able to reach the XL Businesspark. This is clearly not the case. At some times during the day, Nijverdal and Hengelo can just be reached, but anywhere further than that is out of reach. Comparing those locations to Figure 11 and Figure 12, even those areas that are just reachable in 45 minutes, do not satisfy the travel time ratio of 1,5. Those

areas that are reachable are part of the yellow zone, which should be reachable within 30 minutes by public transport. There are even times during the day at which only the area that should be reachable within 15 minutes can be reached within 45 minutes. There are even two times at which there is no public transport at all, which means that the isochrones show the walking distance that can be covered in 45 minutes.

In order to compare accessibility measures with the current situation, maps have been created that display bus stops and train stations that are reachable within one transfer from the bus stop at XL Businesspark. In Appendix C are eight maps displayed that each show the travel time to or from those stops at a specific departure or arrival time at the bus stop at XL Businesspark. Figure 14 summarizes those maps by displaying the average travel time and at how many of the eight departure/arrival times a stop or station is accessible. In the legend can be seen that the colors of the public transport stops and stations refer to the travel time to or from that location to the bus stop near XL Businesspark at the Pastoor Ossestraat. The color scheme represents a travel time ratio of 1,5 compared to the travel time by car. Figure 14 also shows at how many of the eight departure/arrival times the location can reach or be reached from the XL Businesspark. The large circles represent stops and stations that can reach or be reached at all of the eight departure/arrival times. The smaller circles represent stops and stations that can reach or be reached at only some of the eight departure/arrival times. This can for example happen when buses on that line do not drive in the morning or evening.

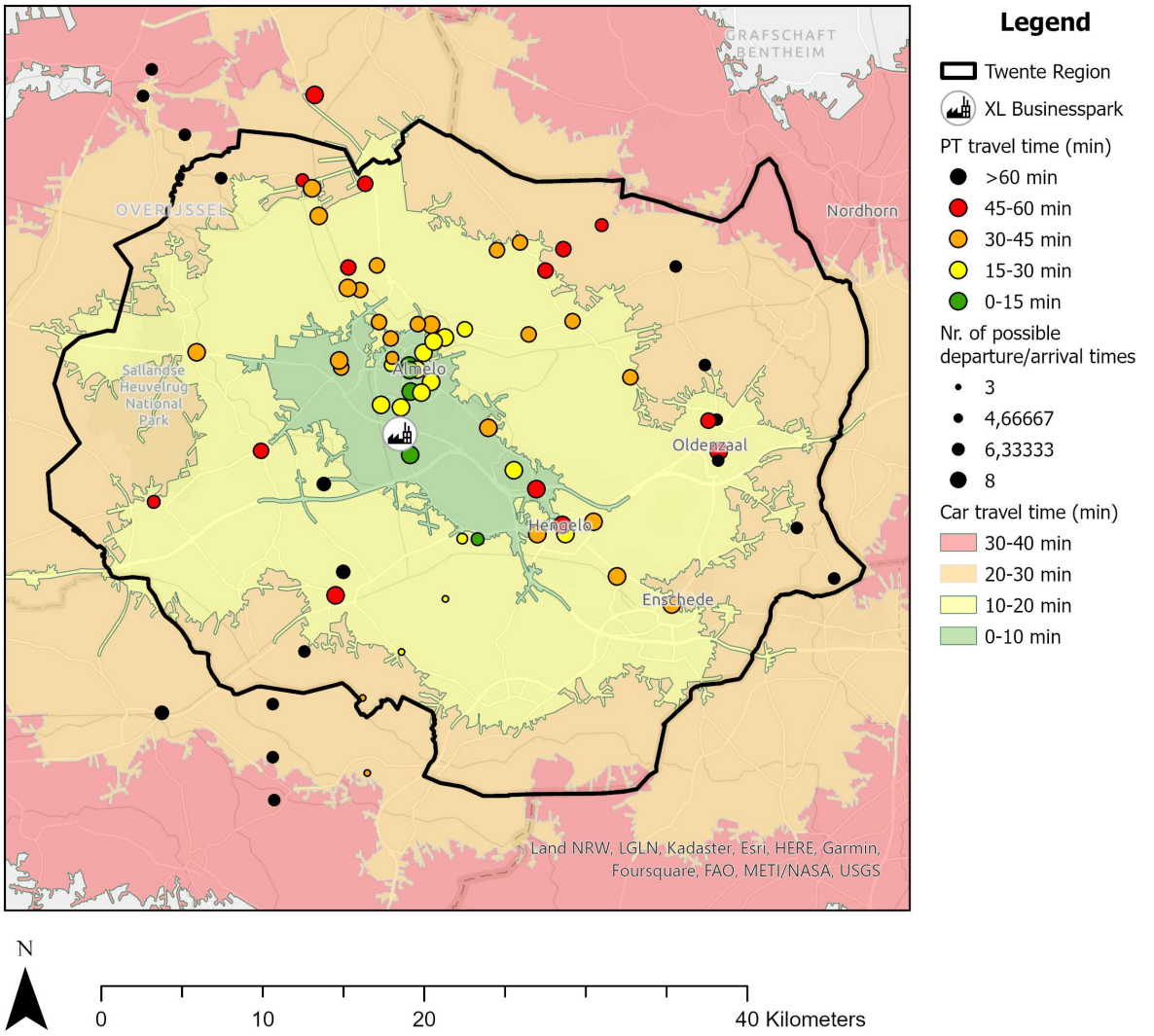

Figure 14: Average travel time to and from bus stops from and to XL Businesspark

Figure 14 however only shows the travel time from the bus stop to a destination, without including the travel time to the bus stop. In Table 8 is shown how much time it approximately takes to walk or cycle between the zones and the bus stop at the Pastoor Ossestraat. Figure 15, Figure 16 and Figure 17 show how the travel time to bus stops and train stations changes when the walking or cycling time from Table 8 is included.

Table 8: Travel time between bus stop and zones

Zone	Walking	Cycling
1	+20 min	+10 min
2	+10 min	+5 min
3	+10 min	+5 min

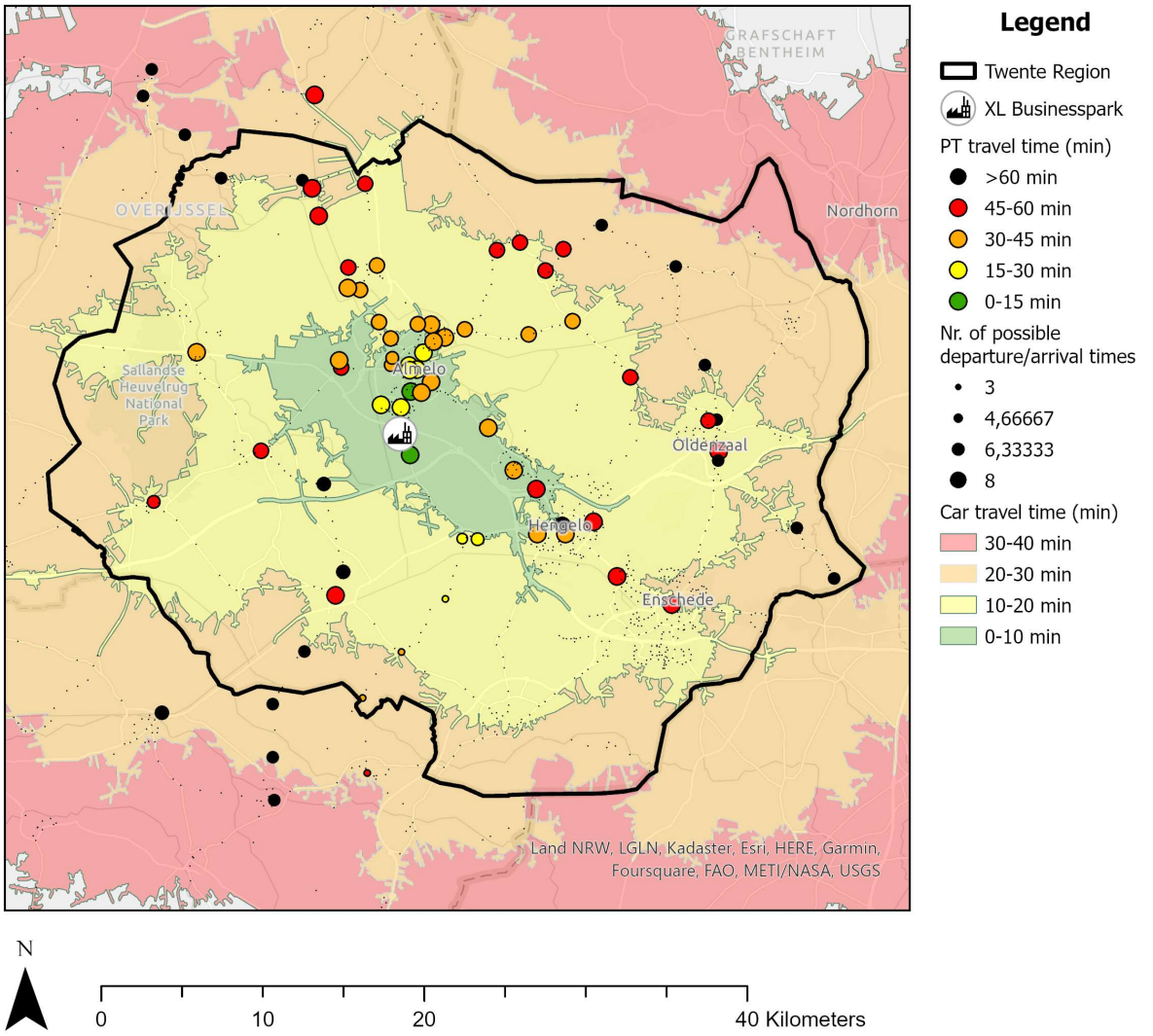

Figure 15: Travel time including 5 min walking/cycling

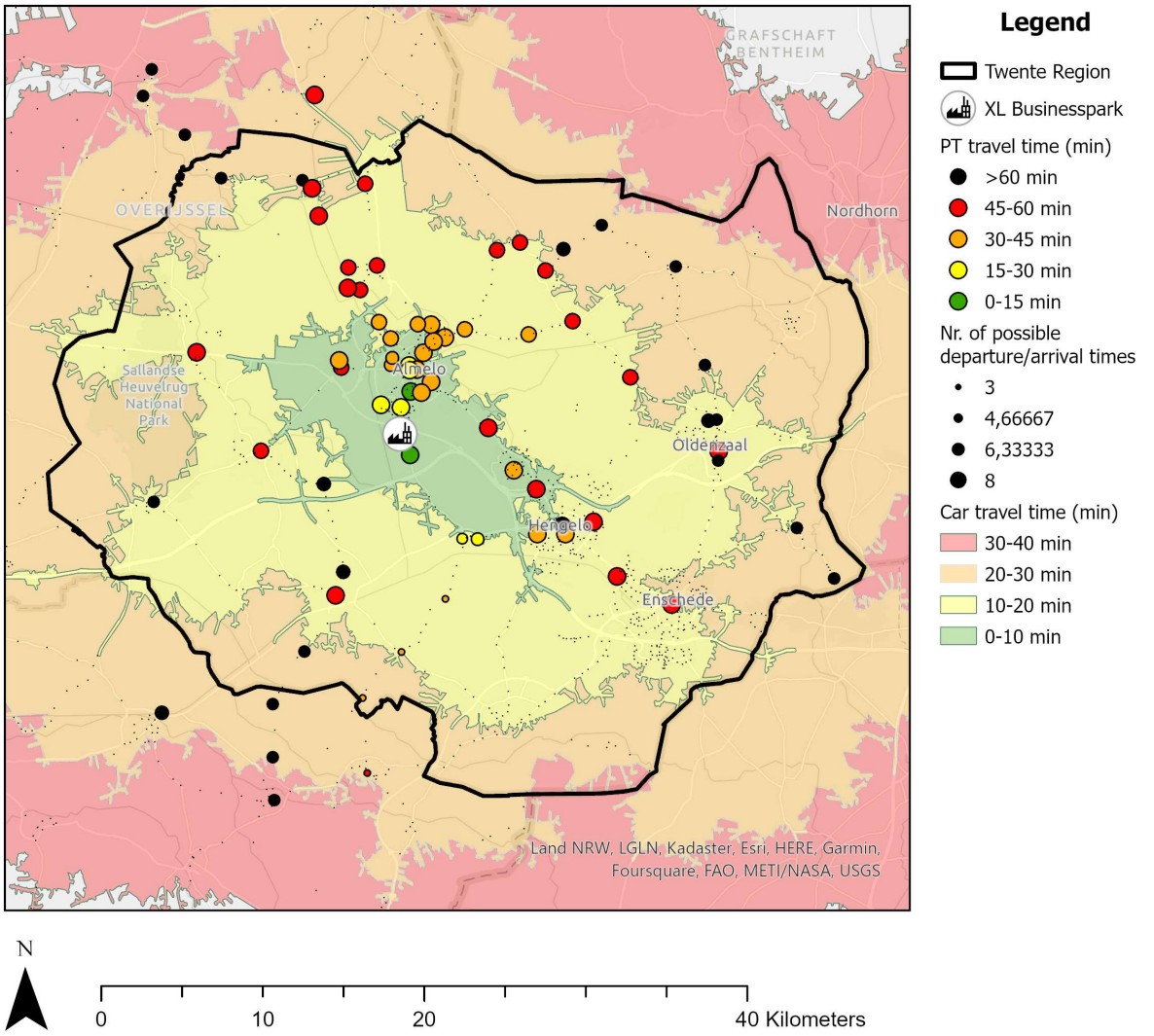

Figure 16: Travel time including 10 min walking/cycling

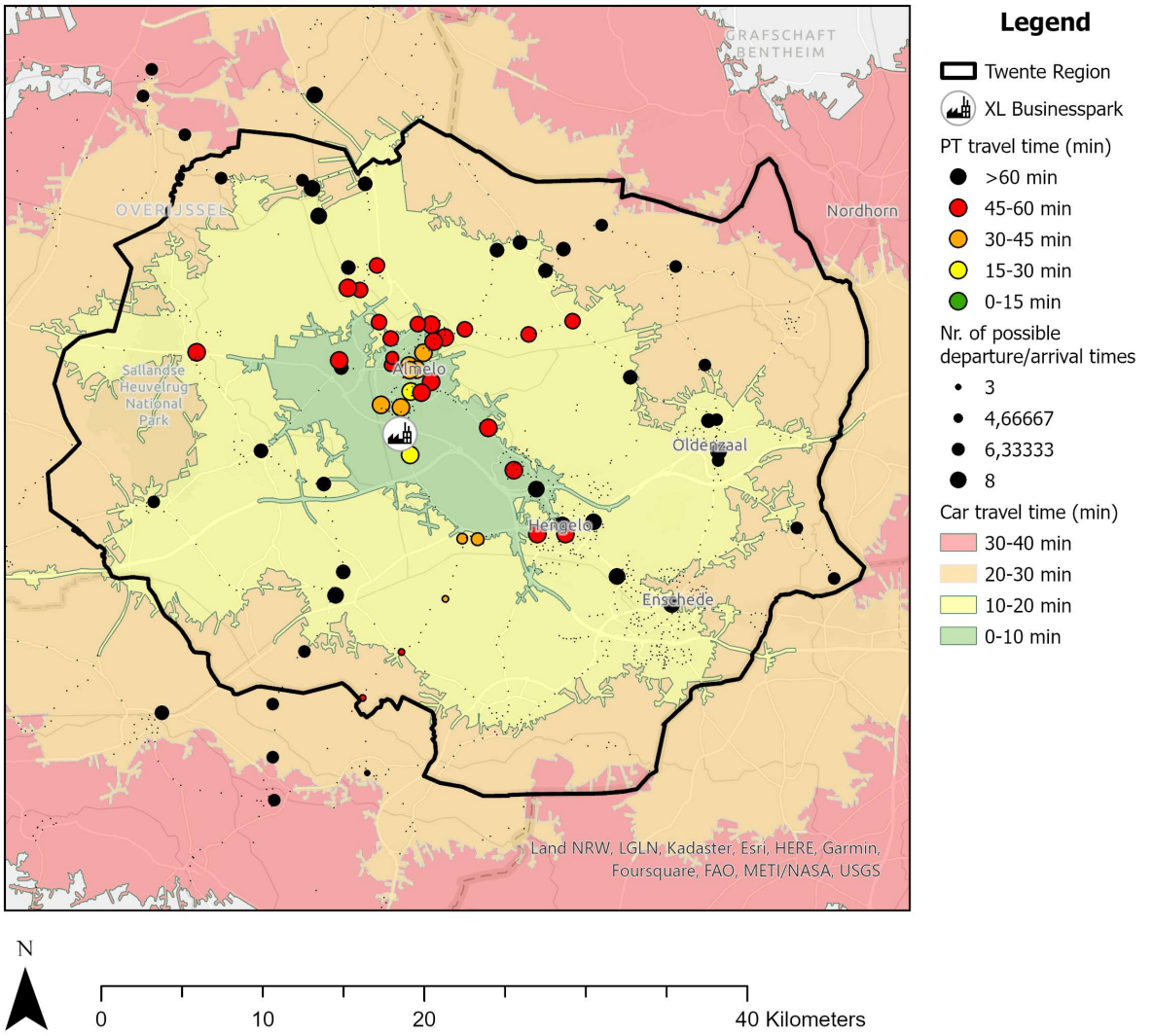

Figure 17: Travel time including 20 min walking

The colors of the stops and stations in Figure 15, Figure 16 and Figure 17 show a more realistic impression of the travel time for employees. These figures still do not include the time between the stops and the employees their homes, so in reality, the travel times are even longer. Although the travel time to an employees' home is even longer, these figures already show that hardly any stop or station can be reached within the preferred travel time ratio of 1,5 compared to traveling by car.

5 Accessibility of XL Businesspark

In order to improve the accessibility of XL Businesspark, the current accessibility is investigated. This is followed by a formulation of the boundary conditions and an exploration of options to improve accessibility by public transport. At the end of this chapter, the effects of the options are analyzed.

5.1 What are the goals and limitations for the alternatives?

5.1.1 Subsidies

Public transport is, as its name suggests, a public service. During a meeting with a public transport policymaker from the Province of Overijssel was explained that 50% of the operating costs for buses are paid by the province. Bakker and Zwaneveld [1] mention that even percentages of 75% are not unusual. Since this is public money, gathered through taxes, the province has a responsibility to spend the money wisely. Therefore decisions on when and where public transport should operate need to be justifiable. In practice, these characteristics of public transport as a public service have two effects. Firstly, citizens need to have a certain level of accessibility to reach important destinations like hospitals, even when those lines are sometimes not necessarily profitable. Secondly, the available budget needs to be spent efficiently. That means operating in a way that is most beneficial for the citizens who paid for it.
In the case of a business park, there can be a conflict between these two factors. It is desirable that employees can reach their job by public transport but if money can more efficiently be spent on other lines, it is hard to justify spending it on XL Businesspark. This implies that for the XL Businesspark, a solution needs to be found where the solution has a better cost/benefit ratio than the current situation.

5.1.2 Volunteer drivers

In the Twente region are two types of public transport that make use of minivans with a capacity for eight passengers: buurtbussen and Twentsflex. The advantage of those services is that they are cheaper to operate because the vehicles are cheaper to run and the drivers are volunteers. A data analyst from OV-Oost however emphasized that these types of services can not operate everywhere. Most people who become volunteers do this because they enjoy it and want to do something useful with their time. Therefore it is not feasible to expect volunteers to drive minivans that are empty most of the time, or drive boring routes. The same counts for the hours at which volunteers work. Voluntary drivers generally only work during the day, because early in the morning or late in the evening is not enjoyable and unfulfilling. These are things that need to be taken into account when making use of these small-scale solutions.

5.1.3 Timetables

In the Netherlands, bus lines do not serve citizens individually, but are part of a public transport network. All the individual parts are connected with each other via the timetable which shows which vehicle is at which location at what time. The public transport maps reveal that in Almelo, the public transport network is focused around one central point: the bus and train station Almelo Centraal. Here, trains depart in four directions and buses from eleven different lines stop. It is important to understand the

structure of this network because transfer time between lines can take up a significant share of the travel time with public transport. At the central station, most buses drive every 30 minutes with some going every 60 minutes during a part of the day. The interesting aspect of the timetable is that all buses depart at the same time and arrive a few minutes before that departure time. This allows for very convenient transfers between buses since it never takes more than a few minutes to transfer between lines. For the modification of bus lines, this is an important aspect to take into account, because a small shift in arrival time can cause a long transfer time to every other bus line, which is very inconvenient. Almelo Centraal is however not the only location of which the arrival time can not easily be changed. Line 66, the bus that runs along the XL Businesspark, currently also has a rather convenient transfer time with the train that runs to Hengelo and Oldenzaal from station Delden. Since it was found in Chapter 4.1.1 that over 15% of the employees live in those cities, it is key that this transfer time also can not be made inconvenient.

5.1.4 List of requirements

Based on Chapters 2 and 5.1, a list of requirements for the alternatives is made. The purpose of this list is to define the goals that are aimed for with the design of the alternatives. Despite their effects, walking distance and volunteer drivers are not included in the requirements. Walking distance is not included because the business park is a large area with many companies. Therefore, it has been chosen to use the walking distance as an evaluation measurement of the alternatives rather than a goal. The volunteer drivers are not included as a requirement but are indirectly included via the costs. This has been done because the ability to use volunteer drivers does not directly suggest that an alternative is good, only that it is cheaper to operate.
Altogether, the following list of goals has been formulated:

1. Travel time ratio compared to car travel must be below 1,5
2. Travel costs for users can not be more than the travel allowance of €0,21/km
3. Trips have at most 1 transfer
4. The cost/benefit ratio needs to be better than the current situation
5. The short transfers of bus line 66 at Almelo Centraal and Delden are kept intact

5.2 Which alternatives could there be implemented?

5.2.1 Buslines

In the past, it has been tried to let a bus run directly between Almelo Centraal and XL Businesspark. At the time, the demand was however not enough for a financially feasible bus line. Therefore this study only focuses on the options to modify the routes of existing bus lines. All lines that stop in Almelo are shown in Figure 18. The XL Businesspark itself is not visible on the map because it is located just south of the area that is covered by the map.

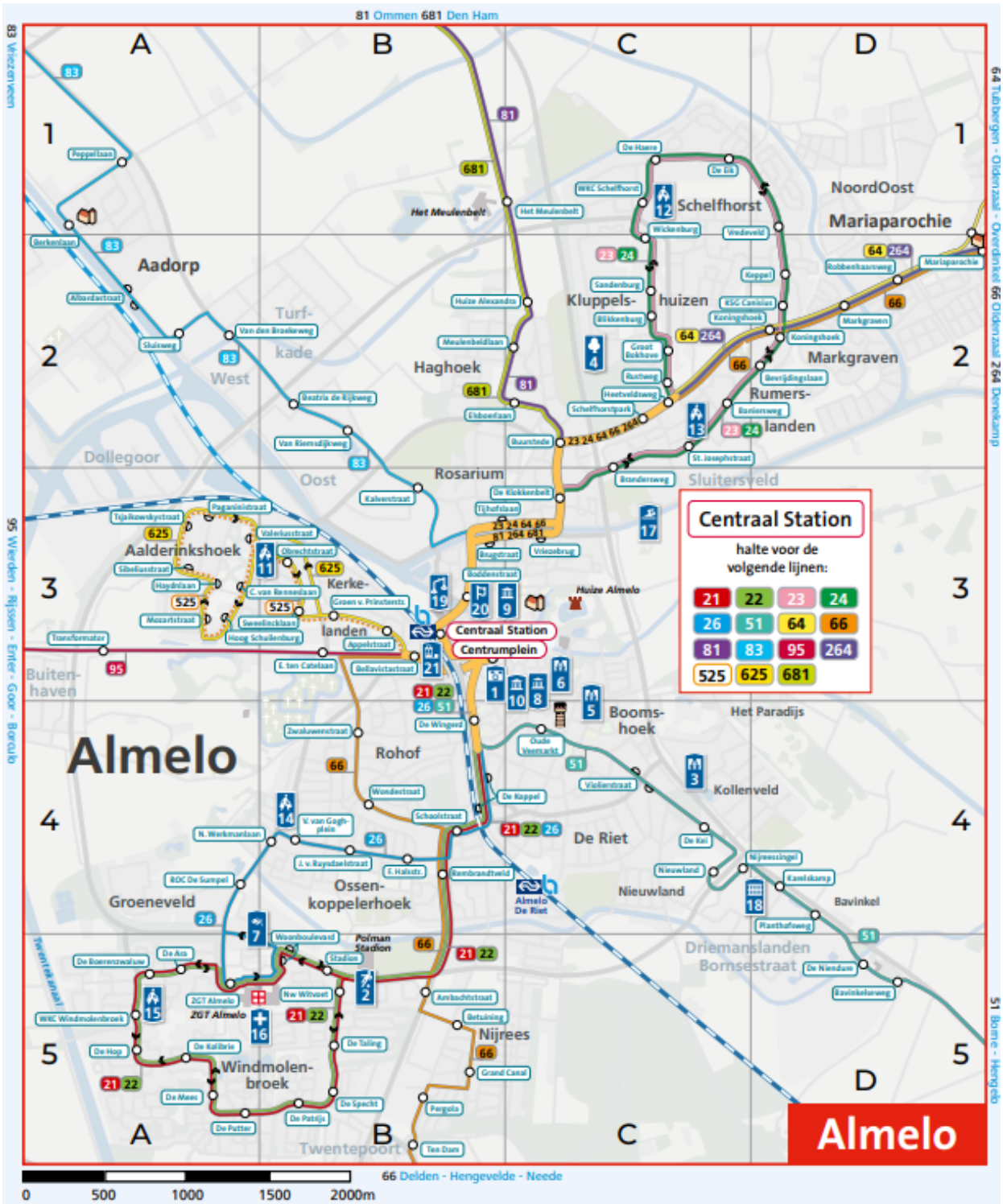

Figure 18: Bus lines in Almelo [17]

The only line that runs sufficiently close to the XL Businesspark to be possible to make a detour across the area is line 66, which passes the area on the Pastoor Ossestraat. Currently, the only way to enter the business park is through the Henriëtte Roland Holstlaan. Letting line 66 stop at the business

park would therefore result in a detour of at least 2,9 km, which takes 4 minutes in a situation without congestion. This is not a realistic scenario, because it would make it impossible to meet the requirement of keeping the attractive transfers at Delden and Almelo Centraal. The parkmanagement has however shown interest in the option of constructing another entrance to the business park via the Pastoor Ossestraat if this provides a significant benefit. If such a connection would be realized, the additional distance and time of a detour would be reduced to such an extent that it becomes possible to create alternatives that fit within the current schedule. Therefore, the alternatives in this section have been developed under the assumption that a connection between the business park and Pastoor Ossestraat could be realized.

In order to let line 66 keep its short transfer times at Almelo Centraal and Delden, the additional time that it takes to serve the XL Park has to be compensated elsewhere. The lines that were considered for this purpose are lines 21, 22, 26 and 95. During the investigation, lines 21, 22, and 26 were found to be impractical for this purpose since they have a tight schedule with little buffer and serve relatively many passengers. Modifying those lines would mean that stops that are used by 15-20 passengers/day would have to be abandoned in order to serve stops that are used by 0-5 passengers/day. Line 95 did show potential due to its buffer of 5-7 minutes at Almelo Centraal, raising the opportunity to let the line make a short detour.

Reducing the additional travel time of line 66 could be done in two segments which are shown in Figure 19 together with the alternative routes for line 66. In segment A, the bus could take the Burgemeester Raveslootsingel instead of its current route along the Schoolstraat and Wierdensestraat, which saves 1,4 kilometers distance and 2 minutes of travel time. In segment B, the bus could after the XL Businesspark return to its normal route through the neighborhood of Nijrees or continue along the Henriëtte Roland Holstlaan which saves 0,9 kilometers and 2 minutes in a situation without congestion.

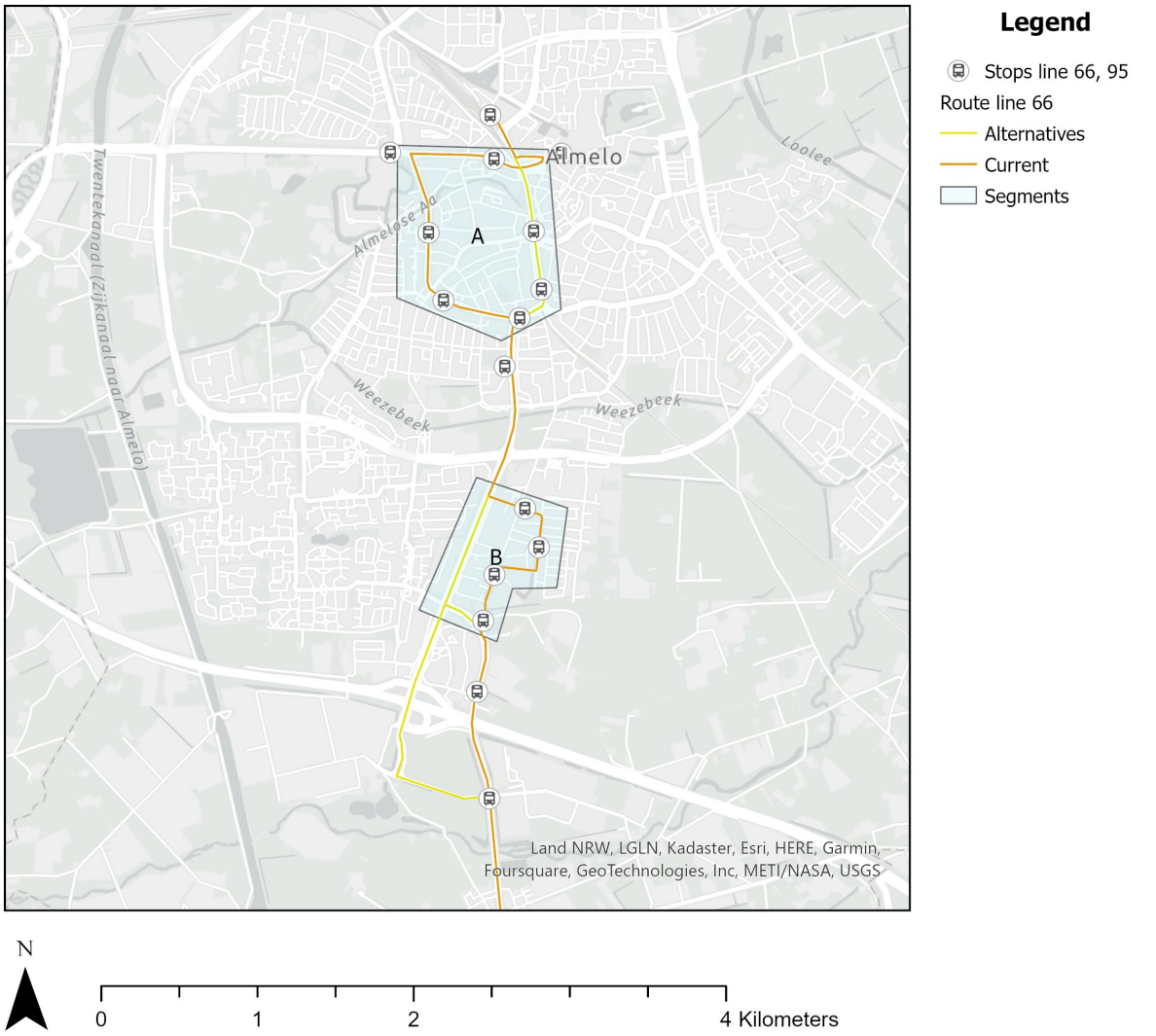

Figure 19: Line 66 segments and alternative routes

Line 95 also passes through segment A. When line 66 would take the alternative route in this segment, line 95 could sacrifice one stop at its line to stop at two of the three stops that are currently served by line 66. This detour would take line 95 1,5 kilometers and 2 minutes longer without congestion. How this configuration of line 95 would look is shown in Figure 20.

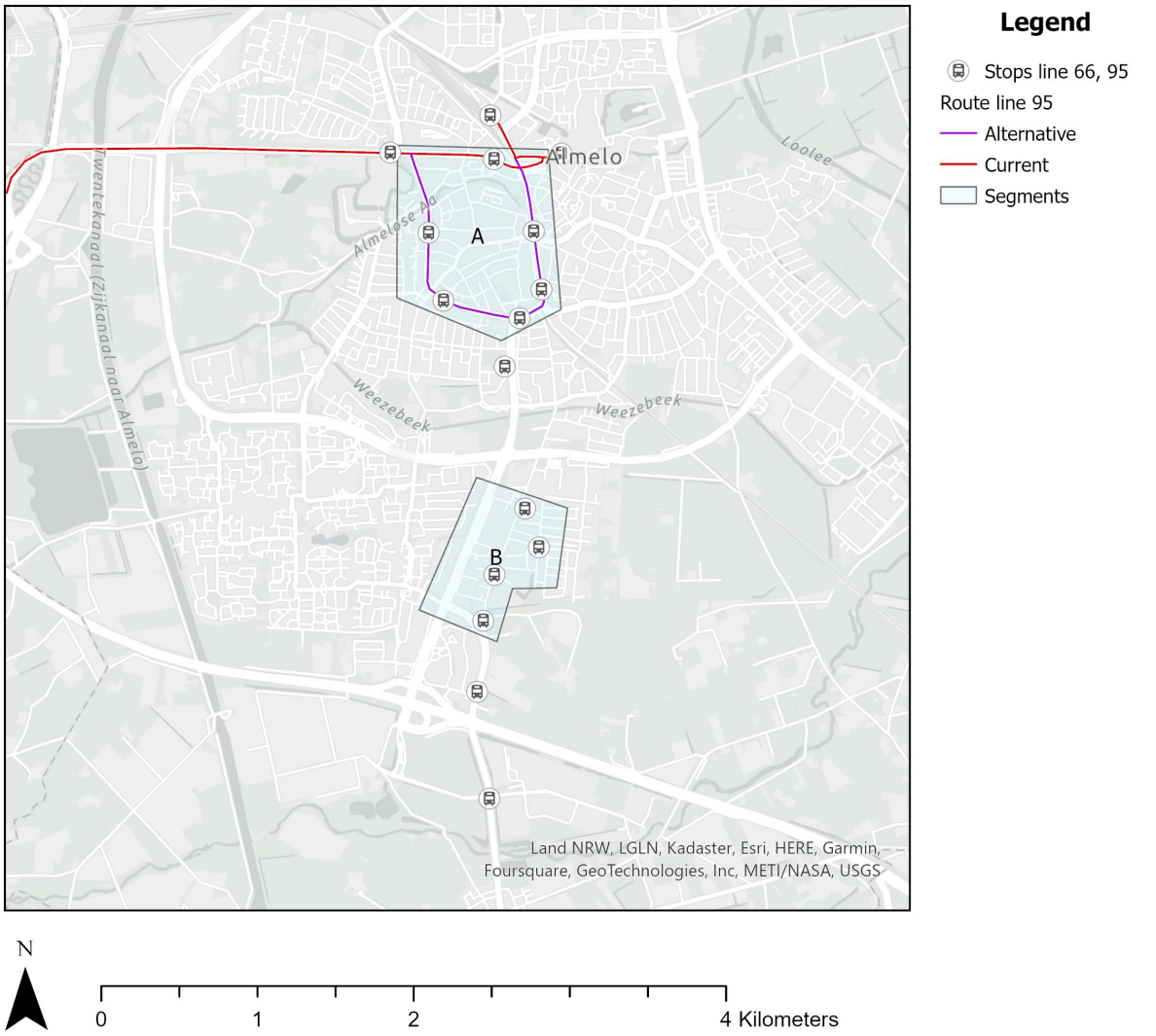

Figure 20: Line 95 alternative route

Based on these possibilities, three alternatives have been derived, which are shown in Figure 21, Figure 22 and Figure 23 and summarized in Table 9. In alternative 1 takes line 66 the alternative route across the Burgemeester Raveslootsingel in segment A while all other parts remain the same. Alternative 2 is the same for line 66, but in this case, line 95 takes the alternative route to pick up the passengers that line 66 can not. In alternative 3, both lines follow their regular route in segment A, while line 66 skips Nijrees in segment B.

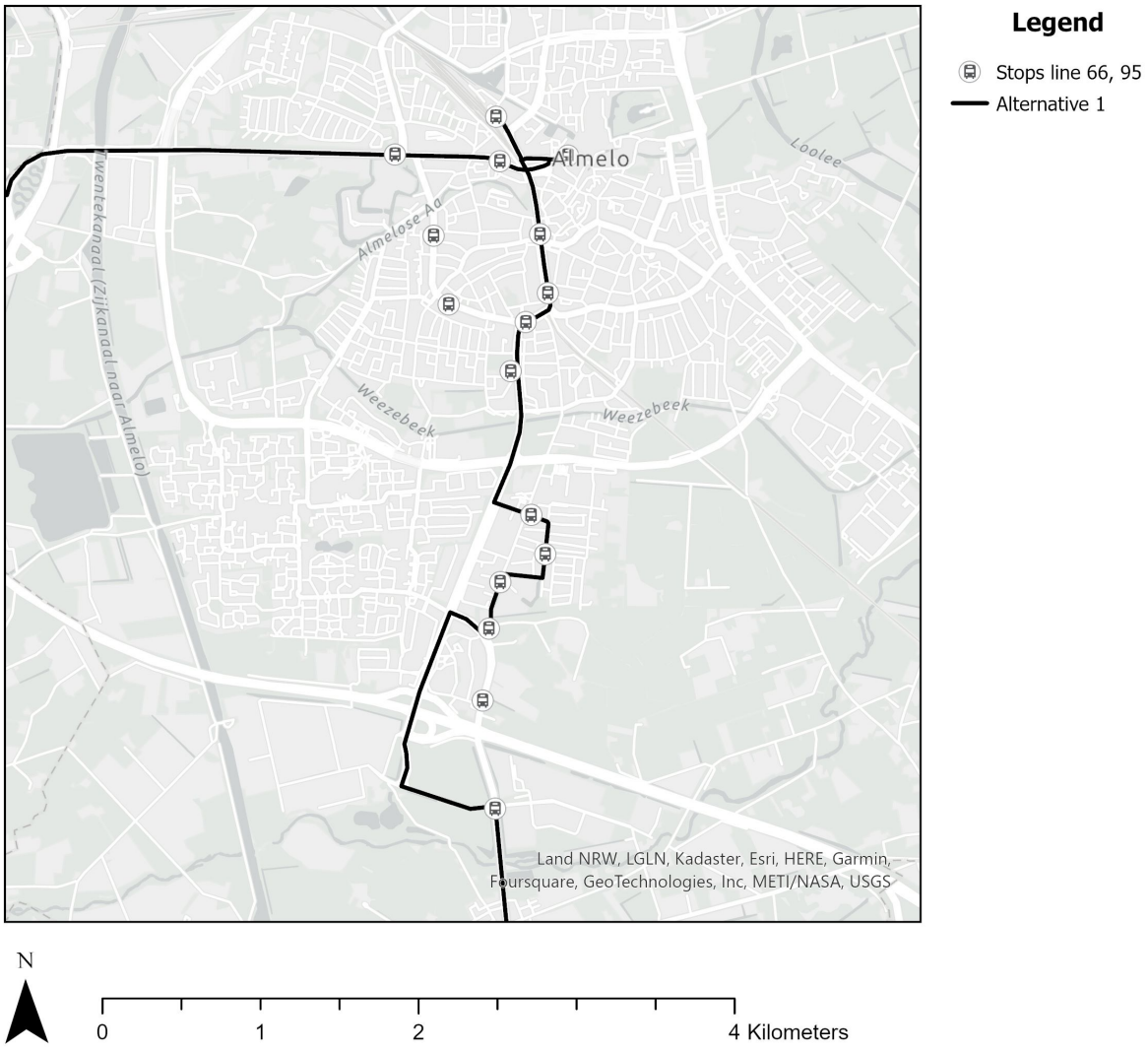

Figure 21: Alternative 1

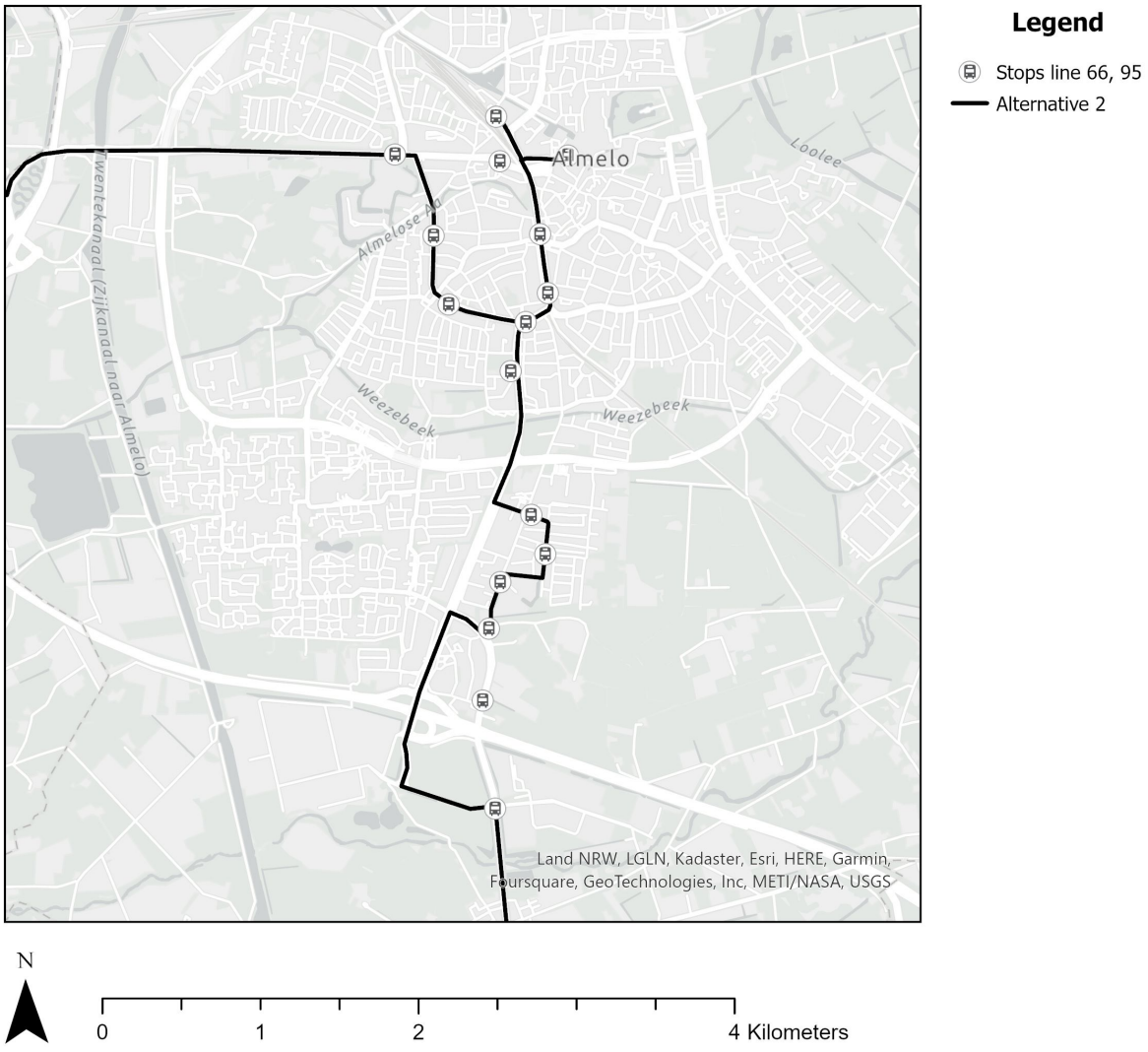

Figure 22: Alternative 2

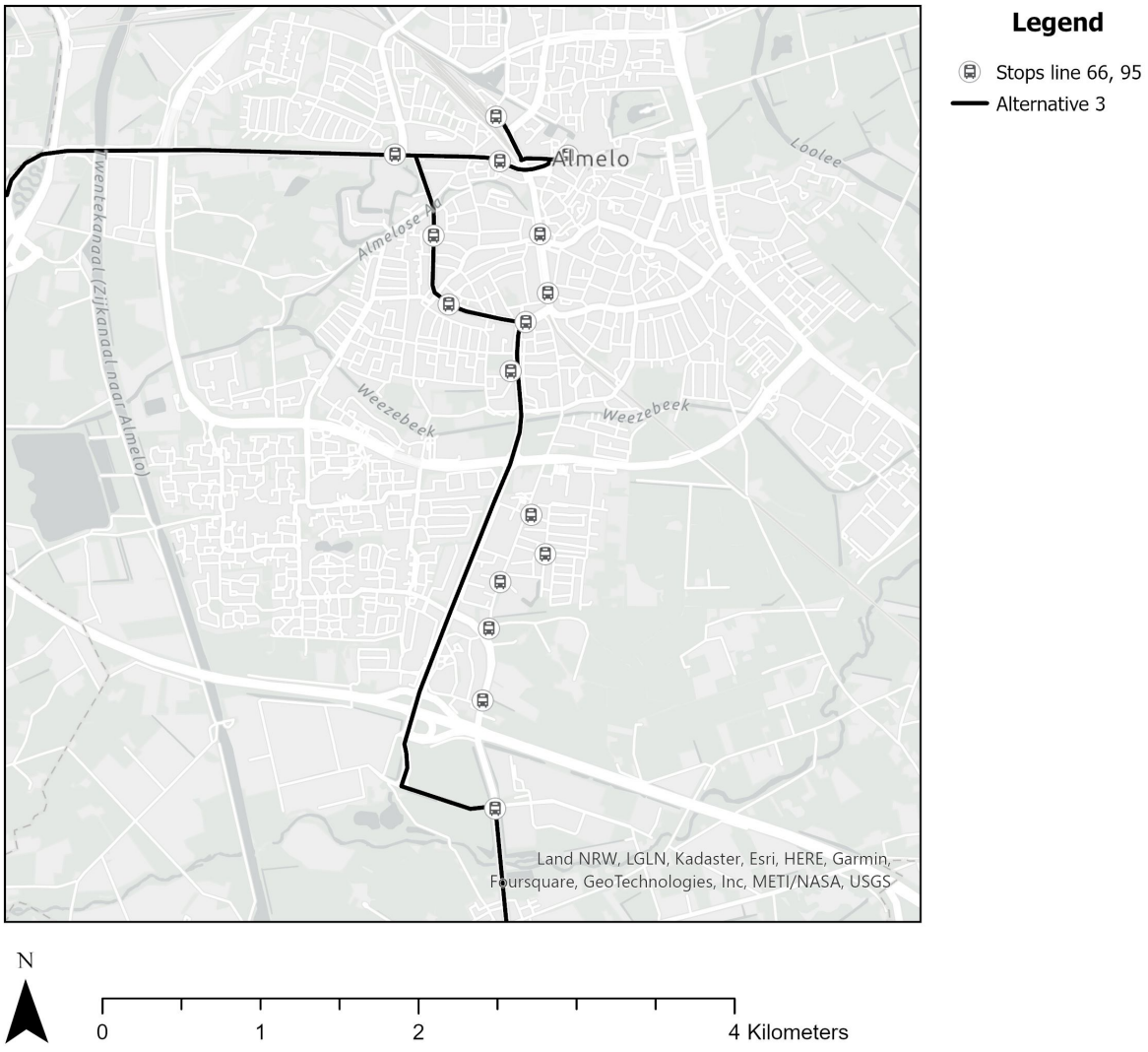

Figure 23: Alternative 3

Table 9: Summary of alternatives

Alternative	Summary of the alternatives		
	66A	66B	95A
1	alternative	current	current
2	alternative	current	alternative
3	current	alternative	current

5.2.2 Shuttlebus

Demand-driven public transport is a promising option for XL Businesspark, since a tailor-made approach can take into account all the special requirements that a business park has compared to regular buses. For this study, a few different options for flexible public transport have been considered and investigated.

The first option is a shuttle bus between the XL Businesspark. This would be a cheaper alternative to the option that has been investigated in the past because it would only have to drive a few times during the day. Although this solution could drastically reduce the walking time to the nearest bus stop, the benefit is still rather limited. As shown in Figure 14, the travel time by public transport is already disproportionately long when the walking time is not included. This difference can also not be overcome by a direct route to Almelo Centraal, since line 66 only takes 4 minutes longer compared to the fastest route by car.

The second option is the implementation of Twentsflex in Almelo. The benefit of this solution is that the transfer time is eliminated because the passenger decides the start and end location. The problem with this approach is however, that Twentsflex is based on the principle of a flexible schedule and a time-frame of 45 minutes in which people are brought to their destination. Applying this principle to commuters within Almelo raises the problem that the time frame of 45 minutes makes most trips longer than they would currently take by public transport. Only very specific trips within Almelo would benefit from a Twentsflex type of service, which makes it impossible to make it financially feasible.

The third option is the most promising form of flexible public transport; a shuttle bus between the business park and Enschede, Hengelo and/or Oldenzaal. The beauty of this option is that it removes the disutility of traveling to Almelo Centraal or Delden and transferring to another line. Instead, it makes use of the excellent highway connection that employees who travel by car also benefit from. Such a shuttle bus could drive a flexible route like Twentsflex does or it could follow a fixed route. Based on the postal codes from employees, one example of a fixed route has been constructed to Enschede and one that goes to Oldenzaal, via Hengelo. These routes are shown in Figure 24. They are constructed in such a way, that they fit within a travel time ratio of 1,5 compared to the time that it would take by car.

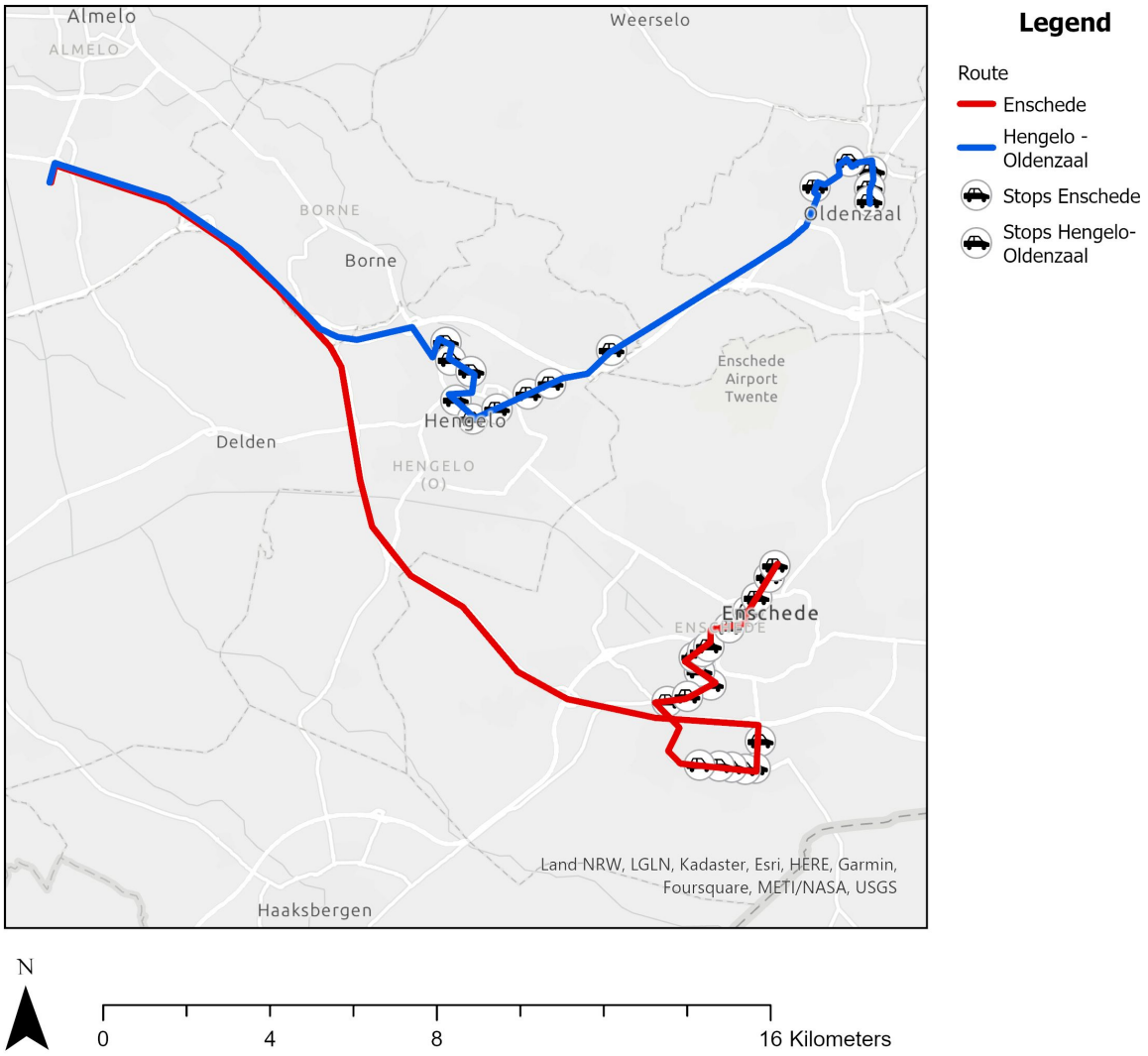

Figure 24: Shuttlebus routes

The operation of a shuttle bus is the easiest to do with a minibus with a capacity of 8 passengers because this has some benefits over a large bus. Firstly, these buses do not require a special driving license, which makes it easier to let employees or volunteers drive. Secondly, minibusses are more suitable for the implementation of flexible routes because there are fewer passengers that need to be taken into account.

5.3 What impact would the alternatives have on the accessibility of XL Businesspark?

The goal of the measures is to improve the public transport accessibility of XL Businesspark. Both the modified bus lines and shuttle bus alternatives achieve this but in different ways. The effect of the modified bus lines can be found in the walking distance between companies at the XL Businesspark and the nearest bus stop. The shuttle bus has a much broader effect between it not only shortens the walking distance between companies and the bus stop but also removes the transfer and possibly

reduces the distance between the stops and employees their homes. An advantage of the modified bus lines is however that an employee does not have to live in a specific city to benefit from the measure, like with the shuttle bus.

5.3.1 Buslines

The main impact of the alternative bus line configurations is the distance to the nearest bus stop for companies in zone 1 or 2. Therefore a network analysis has been done on the walking distances to the bus stops in the existing situation and the new situation. During this study, a company located at business park Twentepoort West also showed interest in better public transport. This businesspark is located close to XL Businesspark, but on the other side of the highway and west of the Henriëtte Roland Holstlaan. Because Twentepoort, both east and west of the H. R. Holstlaan, are influenced by a rerouting of the bus line, these areas are also taken into account in the walking distance analysis. The bus stops that are used are shown in Figure 25.

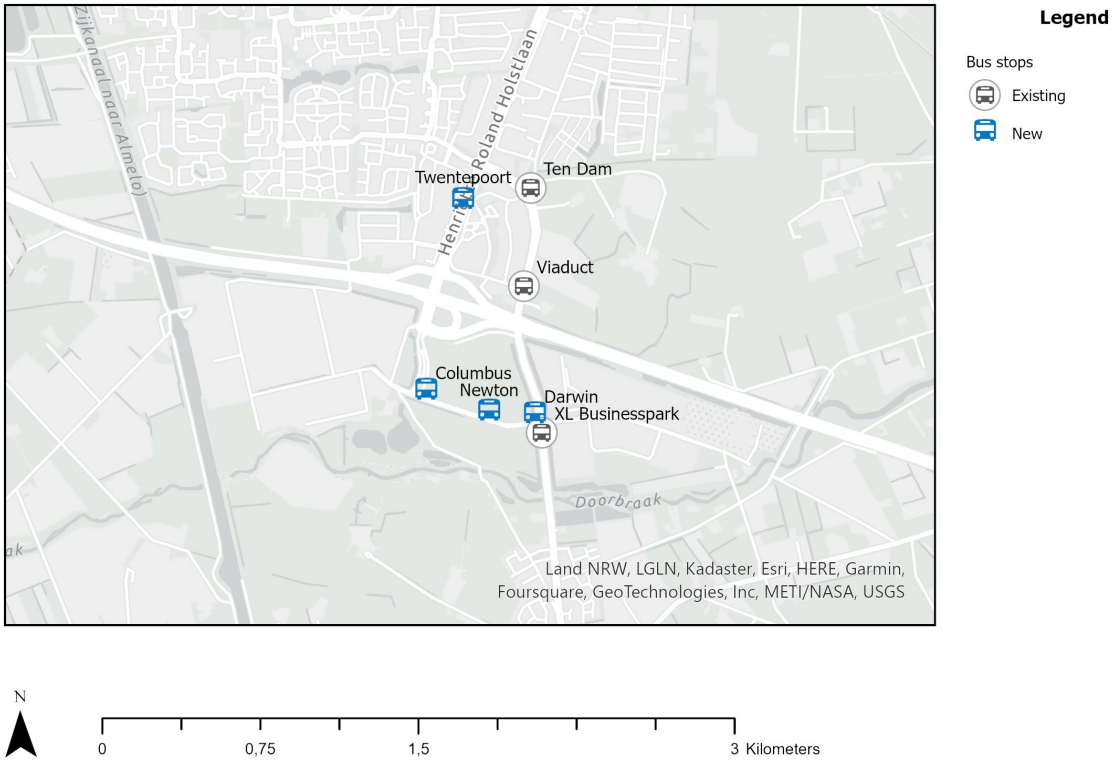

Figure 25: Existing and new bus stops at XL Businesspark and Twentepoort

The effects of the new bus stops on the walking distance can be seen in Figure 26 and Figure 27. Especially the companies in Zone 1 benefit from the new bus stops because it saves 600 meter of walking distance, which takes approximately 7 minutes. Although that is an improvement, still not all companies are located in the 200-500 meter range that is discussed in Section 2.2.5. The companies in the northwest corner are still 1,6 kilometers away from the nearest bus stop.

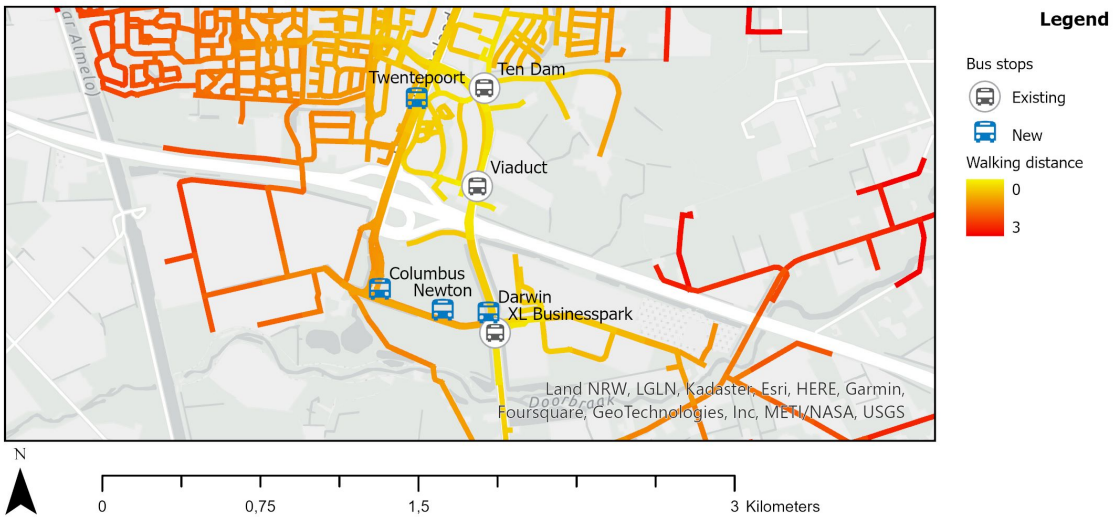

Figure 26: Walking distance to bus stops in current situation

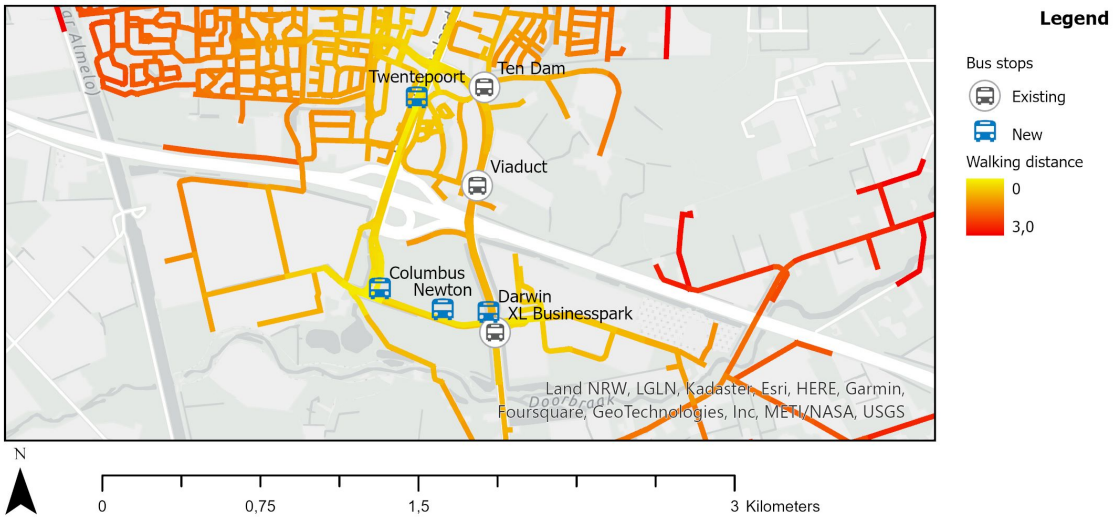

Figure 27: Walking distance to bus stops in new situation

5.3.2 Shuttlebus

The accessibility improvements of a shuttle bus depend largely on the number of people who make use of it and where they live. The more people use it, the easier it is to drive a route that only goes to certain areas, which reduces the travel time. To analyze the accessibility improvements of a shuttlebus service, travel time measurements have been done in Google Maps, which are shown in Table 10. It can be seen that most employee trips are estimated to be within or close to the travel time ratio of 1,5

compared to how long it would take by car.

Table 10: Travel time with a shuttlebus

Part	Destination		
	Enschede	Hengelo	Oldenzaal
Company - Minibus	5-10	5-10	5-10
XL Park - City	20-25	15-20	30-35
City - Home	5-10	5-10	5
Total	30-45	25-40	40-50

The example routes that are shown in Figure 24 have been used to analyze how many people would be in reach of the stops on these routes and how long those people would travel. The total travel time that is required for the routes is approximately 40 minutes according to Google Maps. Adding a buffer of 1,5 km around the stops shows how many people live within a 5-minute cycling distance of a stop, which is shown in Figure 28 and Figure 29.

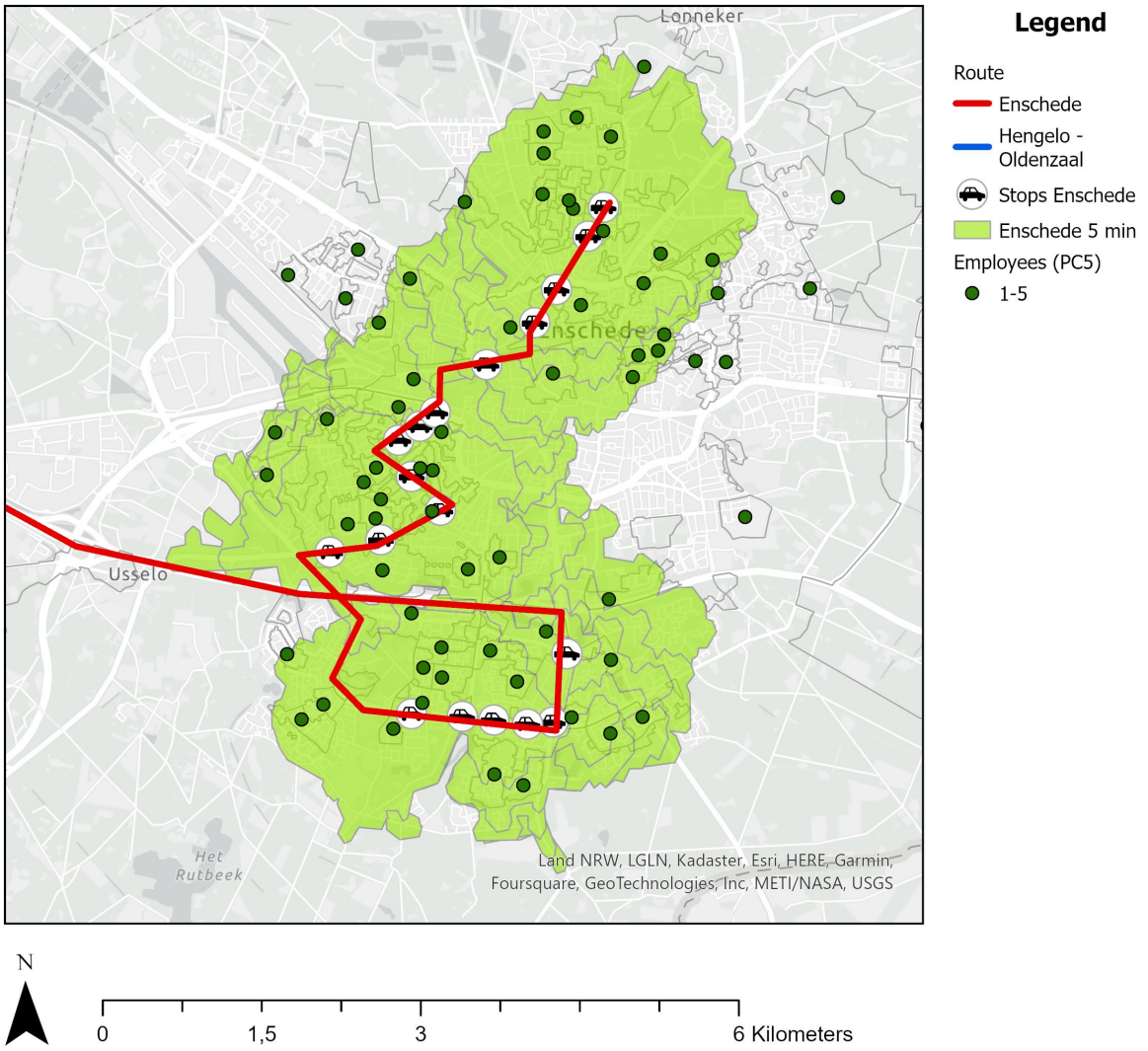

Figure 28: Employees from Enschede within 5 min of a stop

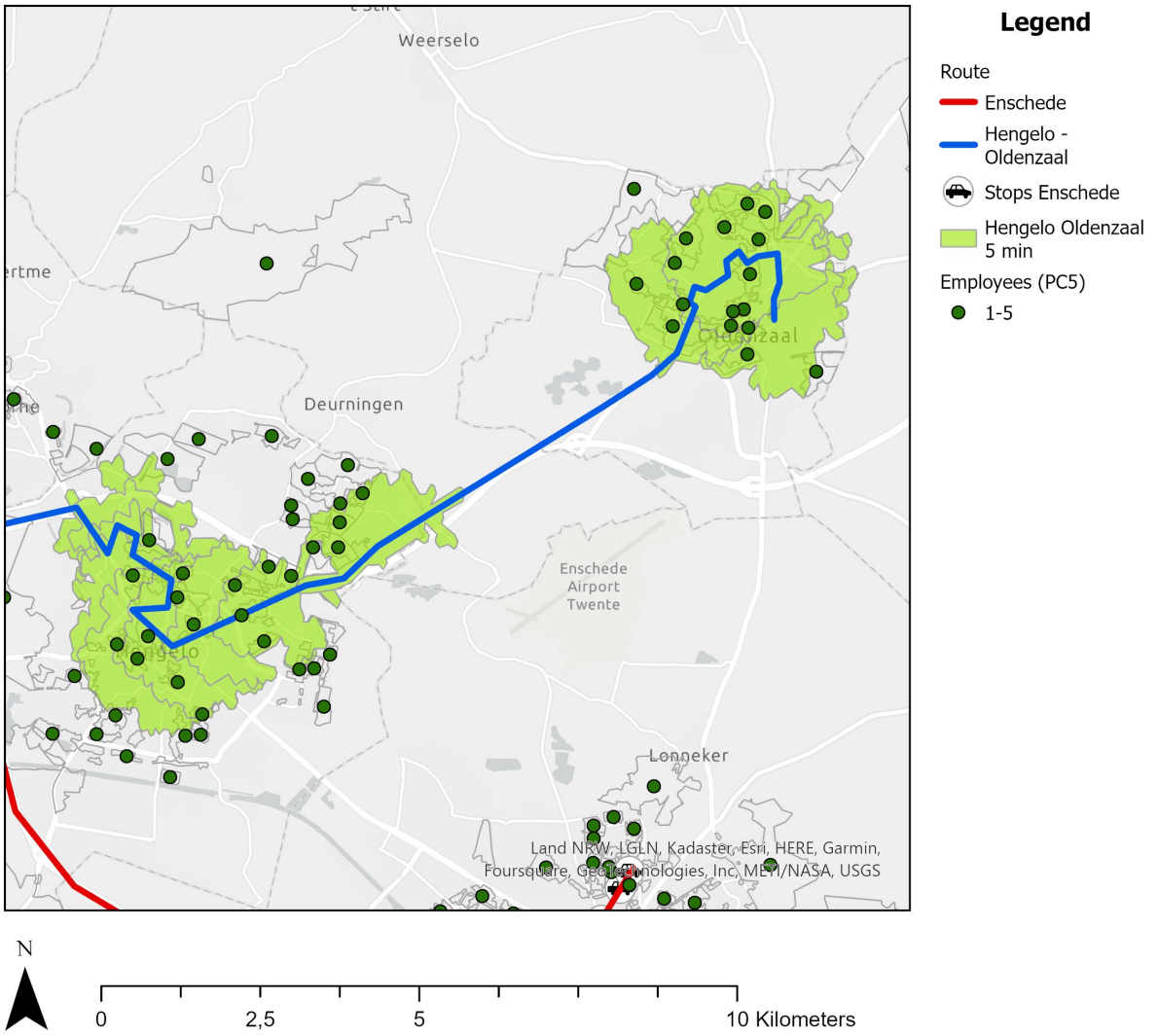

Figure 29: Employees from Hengelo and Oldenzaal within 5 min of a stop

The result of the analysis is that about 80 of the 110 people from Enschede live within 5 minutes from a stop of the route and about 50 of the 75 people who live in Hengelo or Oldenzaal live within 5 minutes of one of the stops through those cities.

5.4 What would be the costs and benefits of the alternatives?

5.4.1 Buslines

The additional costs for the alternative bus routes are negligible. Applying the cost guidelines of CROW-KpVV [3] results in an additional cost of €12,96-€17,28 per day for the 1,5 km detour of line 95.

The potential benefits of the bus lines are estimated by investigating the number of users of bus stops that are skipped in an alternative. It is not known where these people went, how much they paid and how they would travel if the bus takes a different route. Therefore it only gives a rough impression

of how many users the new routes would need to be more profitable than the current routes. It is however an interesting number to compare the alternatives because the new stops are the same for all alternatives. The abandoned stops are therefore determined for the number of passengers that is served by each alternative. An overview is given in Table 11. It can clearly be seen that alternative 3, which skips the neighborhood Nijrees, misses about three times as many passengers as the other two.

Table 11: Passengers missed by alternatives

Segment	alternative 1	alternative 2	alternative 3
A	5-10	15-20	
B	5-10		55-60
Total	15-20	15-20	55-60

5.4.2 Shuttlebus

According to traveler association Rover [13] the costs for a minibus with a volunteer driver are €20/hour and for a minibus with a paid driver €60/hour of which €35-€50 is paid by the province, leaving €10-€25/hour which needs to be paid by passengers. As discussed in Section 5.3.2 a single trip takes approximately 45 minutes. What the resulting costs per passenger are depends on the average amount of passengers. This amount is not only influenced by the number of employees who make use of the shuttle bus but also by whether the vehicle is full in both directions or only in one. Using the guideline of €20/hour, an overview of what the costs per passenger are depending on the number of passengers per trip is given in Table 12.

Table 12: Shuttlebus costs/passenger/trip

Avg. nr. of passengers	costs/passenger/trip
8	€1,88
7	€2,14
6	€2,50
5	€3,00
4	€3,75
3	€5,00
2	€7,50
1	€15,00

It can be observed that it is key that the vehicles are as full as possible in order to keep the costs low.

Most employees receive a travel allowance of €0,21/km. Based on the number of employees from each

city, and the distance to those cities, the average travel allowance of employees from Enschede, Hengelo and Oldenzaal is €5,15. If the ticket price for the shuttle bus would be equal to the travel allowance, it should carry at least 3 passengers/trip on average to make the shuttle bus profitable.

6 Multi-Actor Multi-Criteria Analysis

The five stakeholders that are considered in the multi-actor multi-criteria analysis are the province of Overijssel, the municipality of Almelo, public transport company Arriva, companies at XL Businesspark and employees at XL Businesspark. The opinions of the first four stakeholders have been derived from the meetings and interviews listed in Table 13 and the criteria and weights of the employees have been derived from a research paper in which the impact of different factors is quantified [8].

Table 13: Overview of stakeholder interviews

Organization	Function of interviewee
Province of Overijssel	Public transport policymaker
	Concession manager
	Sustainable mobility advisor
Municipality of Almelo	Senior traffic consultant
	Senior accountmanager
Arriva	Transport developer
Company XL Businesspark 1	HR manager
Company XL Businesspark 2	HR manager
Company XL Businesspark 3	HR manager
Company XL Businesspark 4	COO
	Executive assistant CEO
	HR manager

6.1 Stakeholder criteria and weights

In this section, the criteria and relative importance of these criteria are described for each stakeholder.

6.1.1 Province of Overijssel

The province has recently made new agreements for the concession that starts in 2024. During a meeting with the concession manager, the criteria that were set by the province were discussed as well as their relative importance. During this meeting, exact weights were not quantified. Still, it became clear that retaining the current accessibility, despite lower passenger numbers since Covid 19, was the most important criterion. This is closely followed by the reliability of the system. Sustainability and ideas to increase the number of passengers were also taken into account but were far less important than the other two criteria. Based on this information, the criteria and weights in Table 14 have been derived.

Table 14: Criteria of the province of Overijssel

Criterion		Relative weight
1	Retaining current accessibility	0,40
2	Reliability of service	0,35
3	Sustainability	0,15
4	Increasing number of passengers	0,10
total		1,00

6.1.2 Municipality of Almelo

The municipality plays a different role in public transport because it is not primarily their responsibility. They are however interested in the effects of public transport because it is their job to keep the city attractive and citizens happy. During the meeting, they showed a large interest in the outcomes of this study because accessibility of the XL Businesspark was important to them. Besides accessibility, the equality of opportunities that public transport offers to citizens was mentioned as a criterion. Based on this meeting two criteria were found to be of importance, which are shown in Table 15.

Table 15: Criteria of the municipality of Almelo

Criterion		Relative weight
1	Accessibility of XL Businesspark	0,50
2	Accessibility of rest of Almelo	0,50
total		1,00

6.1.3 Public transport company Arriva

During the meeting with Arriva were their plans discussed for the concession and the room for improvements on XL Businesspark. They stressed that public transport is not always a rational decision, but an extension of politics. In the end, their main criteria were the reliability of service and the income that can be generated from selling tickets.

Table 16: Criteria of Arriva

Criterion		Relative weight
1	Reliability of service	0,50
2	Income from selling tickets	0,50
total		1,00

6.1.4 Companies at XL Businesspark

The interest in public transport differs between companies. Some do not experience difficulties without public transport, but others do. The companies who are interested mainly want to be more attractive for their current and future employees, therefore the score that the employees give is taken into account. Besides that, the financial contribution that is required in some cases is taken into account.

Table 17: Criteria of companies at XL Businesspark

Criterion		Relative weight
1	Attractiveness of XL Businesspark	0,50
2	Financial costs	0,50
total		1,00

6.1.5 Employees at XL Businesspark

No interviews with employees have been performed during this study. This decision was made because a representative sample of the employees would require too many interviews. Therefore, the criteria and weights are retrieved from a study on factors that influence public transport use for commuting [8]. Based on that study, the weights are given as shown in Table 18.

Table 18: Criteria of Employees

Criterion		Relative weight
1	Travel time	0,35
2	Travel costs	0,35
3	Number of transfers	0,20
4	Walking distance	0,10
total		1,00

6.2 What is the best alternative for each stakeholder?

For the evaluation of the alternatives, a multi-criteria analysis is performed for each stakeholder individually. In this analysis, I have given every alternative a score between 1-5 on all the stakeholder criteria. The scores have the following meaning:

1. Large deterioration
2. Small deterioration
3. Same/similar to the current situation
4. Small improvement
5. Large improvement

The four alternatives that are considered are the three bus line alternatives discussed in Section 5.2.1 which are referred to as BL1, BL2 and BL3 and the shuttle service that is discussed in Section 5.2.2, which is referred to as SB. The scores of the alternatives on all the criteria can be observed in Table 19.

Table 19: MCA scores

Criteria	Weight	BL1	BL2	BL3	SB
Province					
Retaining current accessibility	40%	2,00	2,00	1,00	5,00
Reliability of public transport	35%	3,00	2,00	2,00	3,00
Sustainability	15%	5,00	5,00	5,00	4,00
Increasing number of passengers	10%	4,00	3,00	1,00	5,00
Municipality					
Accessibility of XL Businesspark	50%	4,00	4,00	4,00	5,00
Accessibility of rest of Almelo	50%	2,00	2,00	1,00	3,00
Arriva					
Reliability of public transport	50%	3,00	2,00	2,00	3,00
Income from selling tickets	50%	4,00	3,00	1,00	5,00
Companies					
Accessibility of XL Businesspark	50%	4,00	4,00	4,00	5,00
Financial costs	50%	5,00	5,00	5,00	2,00
Employees					
Travel time	35%	4,00	4,00	4,00	5,00
Travel costs	35%	3,00	3,00	3,00	4,00
Number of transfers	20%	3,00	3,00	3,00	5,00
Walking distance	10%	4,00	4,00	4,00	5,00

Together with the weights, these scores result in a grade between 1-5 from all stakeholders for all alternatives. These grades are shown in Figure 30. It can be seen that for the province and municipality, only a shuttle bus is expected to be an improvement, while for the companies and employees, all the alternatives would be an improvement over the current situation. An interesting outcome is that a shuttle bus is expected to be the best alternative for all stakeholders except for the companies. This is due to the fact that a shuttle bus could require an investment from the companies, which is not the case for regular bus lines. For some companies, this may not be a problem but it is expected that companies who do not experience accessibility problems are against interventions that require investment from their side.

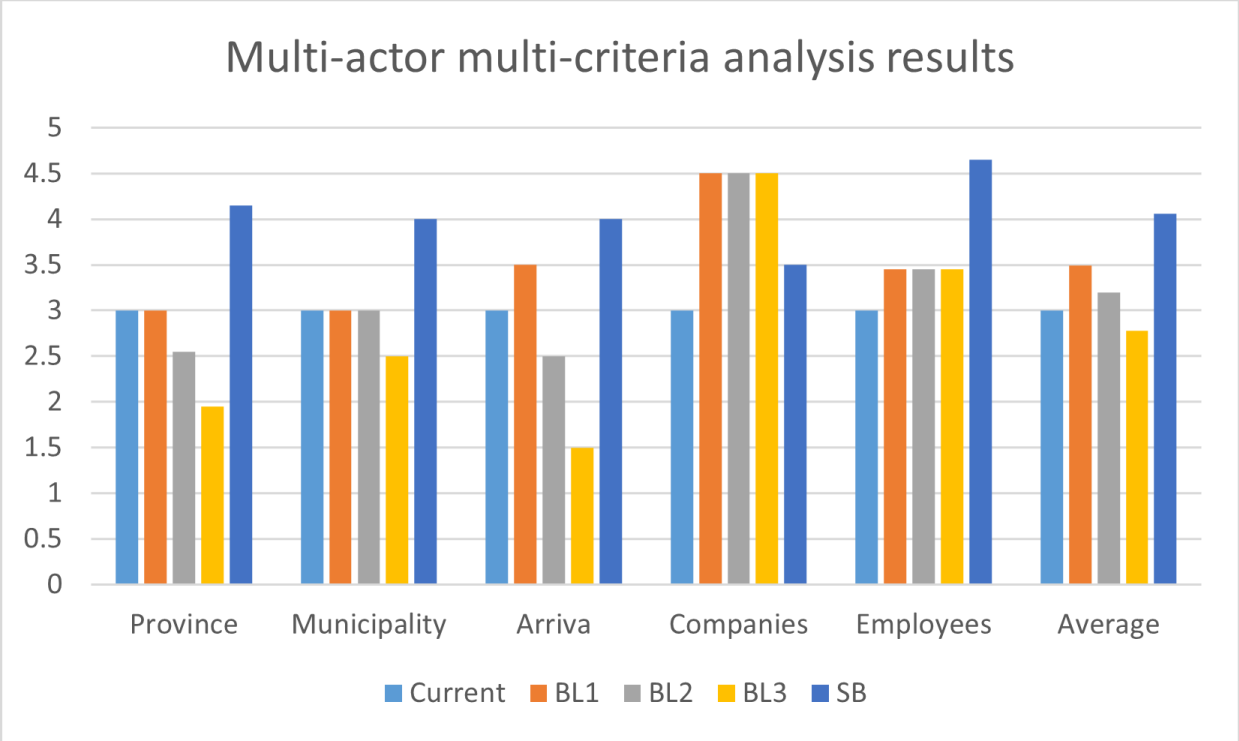

Figure 30: MAMCA outcomes

7 Discussion & limitations

For the purpose of this study, several data sources have been used which are not publicly available. Due to privacy reasons, only limited amounts of public transport data could be accessed for research. This means that it is possible that the outcomes would be different if more data would have been available. Also the number of postal codes that could be investigated was limited. It has been assumed that the data from the three companies would be representative of the entire business park. With more time, it may have been possible to gain access to more postal codes and do more interviews but this was not possible within the time frame of this bachelor thesis.

The time frame has also limited the number of options that could be investigated and the depth to which extent the options could be investigated. More time could have resulted in more detailed versions of the available options and their effects but the relative outcomes of the alternatives would likely remain the same.

8 Conclusion & recommendations

In this report, several steps have been taken to find suitable public transport options to improve the public transport accessibility for employees who work at XL Businesspark. First, the postal codes of current employees were analyzed to gain insights into the locations where they live. From this analysis can be concluded that Almelo, Enschede, Hengelo and Oldenzaal are far and away the most important locations to focus on.

During the accessibility analysis was found that the current travel time by public transport is too long in comparison with car travel times. Three modifications to bus lines and a shuttle bus service were investigated as potential measures to improve accessibility by public transport. It was found that the bus line modifications can reduce the walking distance, but can hardly ever make the travel time short enough to be a suitable alternative to car travel. A shuttle bus could do a better job at this, but its success depends on the number of users, the time at which they travel and the locations where they live. Besides that, a shuttle bus only provides an advantage to those that live in Enschede, Hengelo and Oldenzaal and not to anyone else.

The multi-actor multi-criteria analysis showed that the shuttle bus is the most attractive alternative for most stakeholders. The scores between the three bus lines vary between the stakeholders but in general, the alternatives that keep serving the neighborhood Nijrees perform better in the multi-criteria analysis.

It is recommended to further investigate the demand for a shuttle bus to Enschede, Hengelo and Oldenzaal. Based on the data that was analyzed in this report, this option seems the most promising. More information on how many employees would use it, locations where they live and at which times they travel can tell whether this option only works on paper or would also work in reality. If this option turns out to be viable, it is recommended to search for options to make it a flexible public transport service because a flexible route is likely to save travel time over a fixed route.

Another recommendation is to investigate options to increase the attractiveness of the existing bus stop at the Pastoor Ossestraat. This bus stop currently does not have a platform, rain shelter or bicycle storage, which makes it very unattractive to use. Adding these facilities and transforming the bus stop into a mobility hub for shared e-bikes and e-scooters could potentially improve the user experience of people who make use of it and therefore increase public transport demand. Besides that, mobility hubs on XL Businesspark could potentially decrease the travel time between the bus stop and the company where someone needs to be. Another recommendation is the addition of a pedestrian path between the Pastoor Ossestraat and the west side of XL Businesspark, which would reduce the walking distance to the west side of XL Businesspark.

9 Suggestions for further research

This study has focused on improving the public transport accessibility of the XL Businesspark in its current situation. At the moment, plans are being made for a 70 HA XL Businesspark 2 on the other side of the Twentekanaal. The construction of this business park is planned to start in 2027. When this new business park is in use, further research can reveal new opportunities that are caused by infrastructural developments and extra demand generated by XL Businesspark 2. Therefore it is suggested to keep an eye on the developments that take place related to the new business park and investigate new opportunities when they arise.

References

[1] Peter Bakker, Peter (Peter Jos) Zwaneveld, and Jaco (Jacob) Berveling. *Het belang van openbaar vervoer : de maatschappelijke effecten op een rij*. Kennisinstituut voor Mobiliteitsbeleid, 2009. ISBN: 9789089020468. URL: https://www.cpb.nl/sites/default/files/publicaties/download/het-belang-van-openbaar-vervoer-de-maatschappelijke-effecten-op-een-rij.pdf.

[2] CBS. *Mobiliteit; per verplaatsing, vervoerwijzen, motieven, regio's*. July 2022. URL: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/84711NED/table?dl=91EAB.

[3] CROW-KpVV. *Kostenkengetallen regionaal openbaar vervoer 2021*. Tech. rep. 2021. URL: https://www.crow.nl/downloads/pdf/collectief-vervoer/kostenkengetallen-regionaal-openbaar-vervoer_2021.aspx?ext=.pdf.

[4] CROW-KpVV and Ruimte voor Lopen. *Inzicht in acceptabele loopafstanden*. Tech. rep. CROW, June 2021. URL: https://www.fietsberaad.nl/getmedia/baf3eff0-c37a-4257-8d55-7ecfaceb2c4b/CROW-publicatie-Inzicht-in-acceptabele-loopafstanden_1.pdf.aspx?ext=.pdf.

[5] Mathijs De Haas and Marije Hamersma. *Fietsfeiten: nieuwe inzichten Kennisinstituut voor Mobiliteitsbeleid — KiM*. Tech. rep.

[6] Karst T. Geurs and Bert van Wee. "Accessibility evaluation of land-use and transport strategies: Review and research directions". In: *Journal of Transport Geography* 12.2 (June 2004), pp. 127–140. ISSN: 09666923. DOI: 10.1016/j.jtrangeo.2003.10.005.

[7] Frans Gommers and Sander Wortman. *Openbaar vervoer naar bedrijventerreinen Discussiestuk*. Tech. rep. 2010. URL: www.kpvv.nl..

[8] Jaehyun Ha, Sugie Lee, and Joonho Ko. "Unraveling the impact of travel time, cost, and transit burdens on commute mode choice for different income and age groups". In: *Transportation Research Part A: Policy and Practice* 141 (Nov. 2020), pp. 147–166. ISSN: 09658564. DOI: 10.1016/j.tra.2020.07.020.

[9] Xiaoning Liu et al. "Understanding better the influential factors of commuters' multi-day travel behavior: Evidence from Shanghai, China". In: *Sustainability (Switzerland)* 12.1 (Jan. 2020), pp. 1–13. ISSN: 20711050. DOI: 10.3390/su12010376.

[10] Erik B. Lunke, N. Fearnley, and J. Aarhaug. "Public transport competitiveness vs. the car: Impact of relative journey time and service attributes". In: *Research in Transportation Economics* 90 (Dec. 2021). ISSN: 07398859. DOI: 10.1016/j.retrec.2021.101098.

[11] Cathy Macharis, Astrid De Witte, and Jeroen Ampe. "The multi-actor, multi-criteria analysis methodology (MAMCA) for the evaluation of transport projects: Theory and practice". In: *Journal of Advanced Transportation* 43.2 (2009), pp. 183–202. ISSN: 01976729. DOI: 10.1002/atr.5670430206.

[12] Nibud. *Autokosten*. Dec. 2022. URL: https://www.nibud.nl/onderwerpen/uitgaven/autokosten/.

[13] Werkgroep Kleinschalig OV Reizigersvereniging Rover. *Kleinschalig OV Reizigersvereniging Rover Werkgroep Kleinschalig OV*. Tech. rep. 2020. URL: https://www.rover.nl/images/PDFs/Kleinschalig_OV_versie_14_zwart.pdf.

[14] Rijksoverheid. *Verhoging belastingvrije reiskostenvergoeding naar 0,21*. URL: https://www.rijksoverheid.nl/onderwerpen/belastingplan/arbeid-en-inkomen/reiskostenvergoeding.

[15] K. Schleinitz et al. "The German Naturalistic Cycling Study – Comparing cycling speed of riders of different e-bikes and conventional bicycles". In: *Safety Science* 92 (Feb. 2017), pp. 290–297. ISSN: 18791042. DOI: 10.1016/j.ssci.2015.07.027.

[16] TravelTime. *TravelTime Map demo*. URL: https://app.traveltime.com/.

[17] Twents. "Lijnnetkaart regio Twente". In: (2021). URL: https://www.twents.nl/getattachment/Reisinformatie/Dienstregeling/Keolis_Twente-2021-2022-Lijnennetkaart_web.pdf?lang=nl-nl.

[18] Twents. *Tarieven 2023-Bus & Trein*. Tech. rep. 2023. URL: https://www.twents.nl/getmedia/83ba52f5-cc54-44da-96fd-deda741074e6/Twents-tarieven-2023.pdf.

[19] Frank Witlox et al. "Mobility Management Measures by Employers: Overview and Exploratory Analysis for Belgium The happy Commuter: a life-oriented Approach of commuting Satisfactlon (CASInO) View project Kritische Massa View project Mobility Management Measures by Employers: Overview and Exploratory Analysis for Belgium". In: (2010). ISSN: 1567-7141. URL: www.ejtir.tbm.tudelft.nl.

Appendices

A Bicycle accessibility per zone

In Figure 31, Figure 32 and Figure 33 are the accessibility isochrones shown for each of the three zones of XL Businesspark.

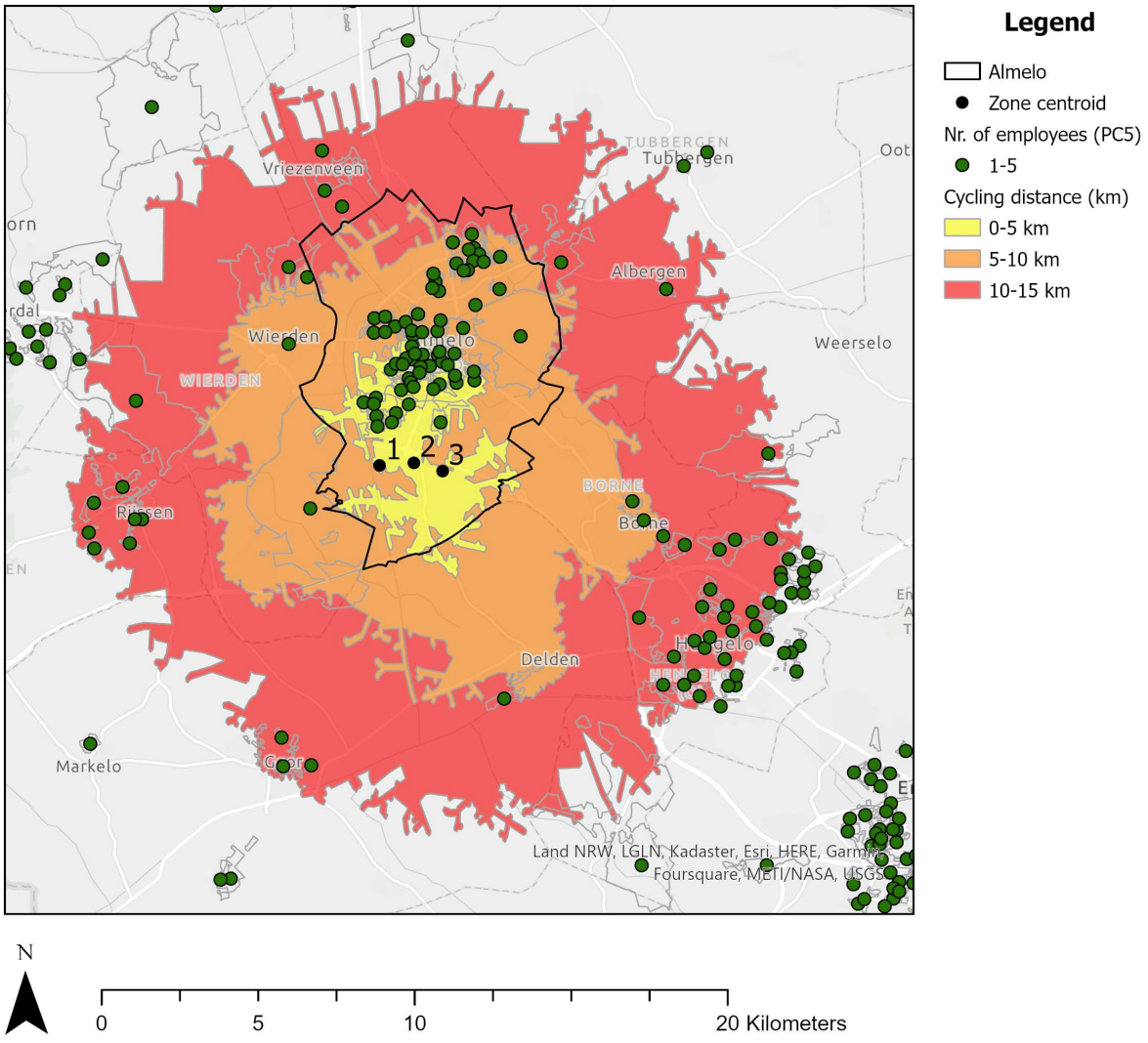

Figure 31: Bicycle accessibility isochrones of zone 1

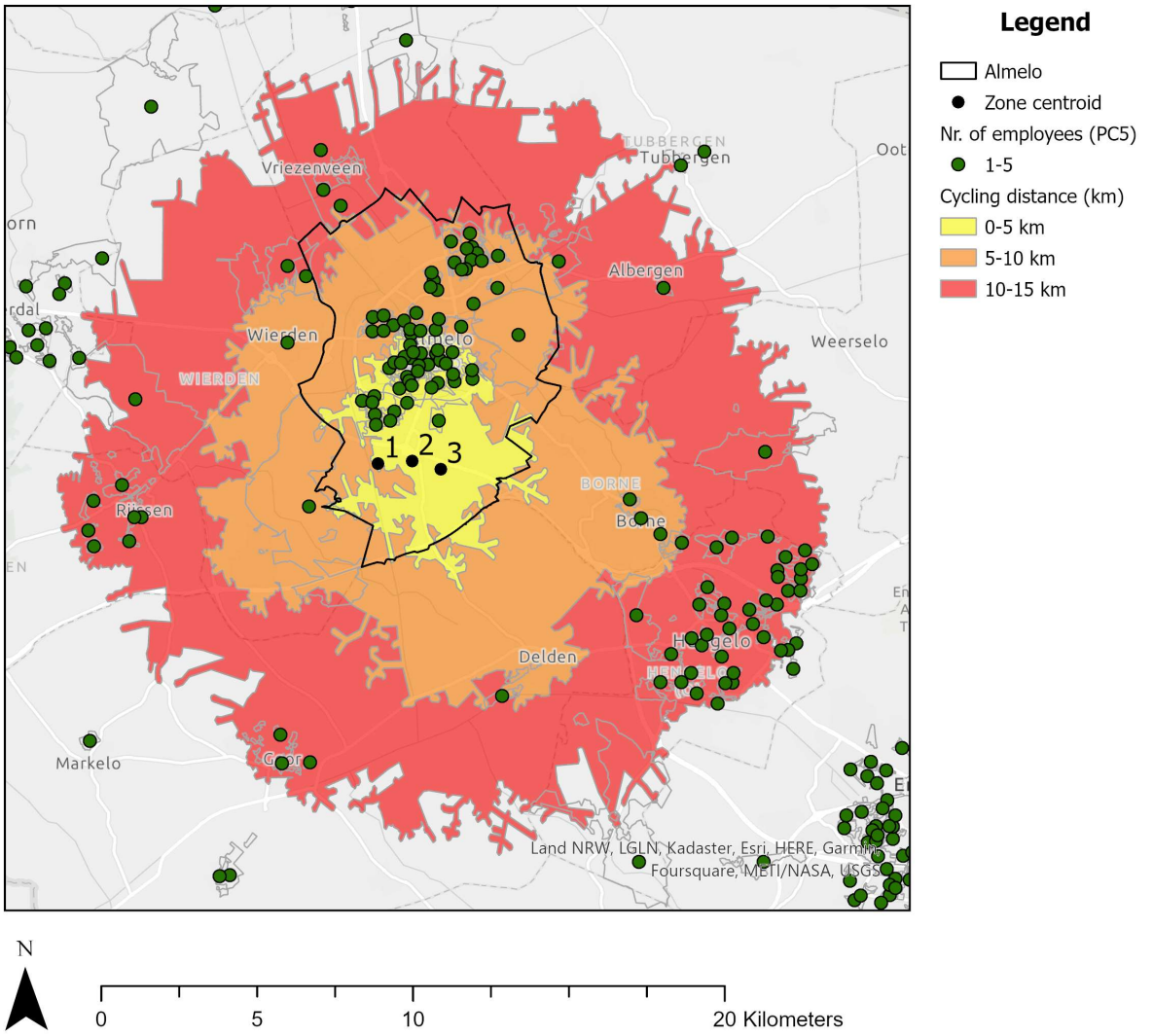

Figure 32: Bicycle accessibility isochrones of zone 2

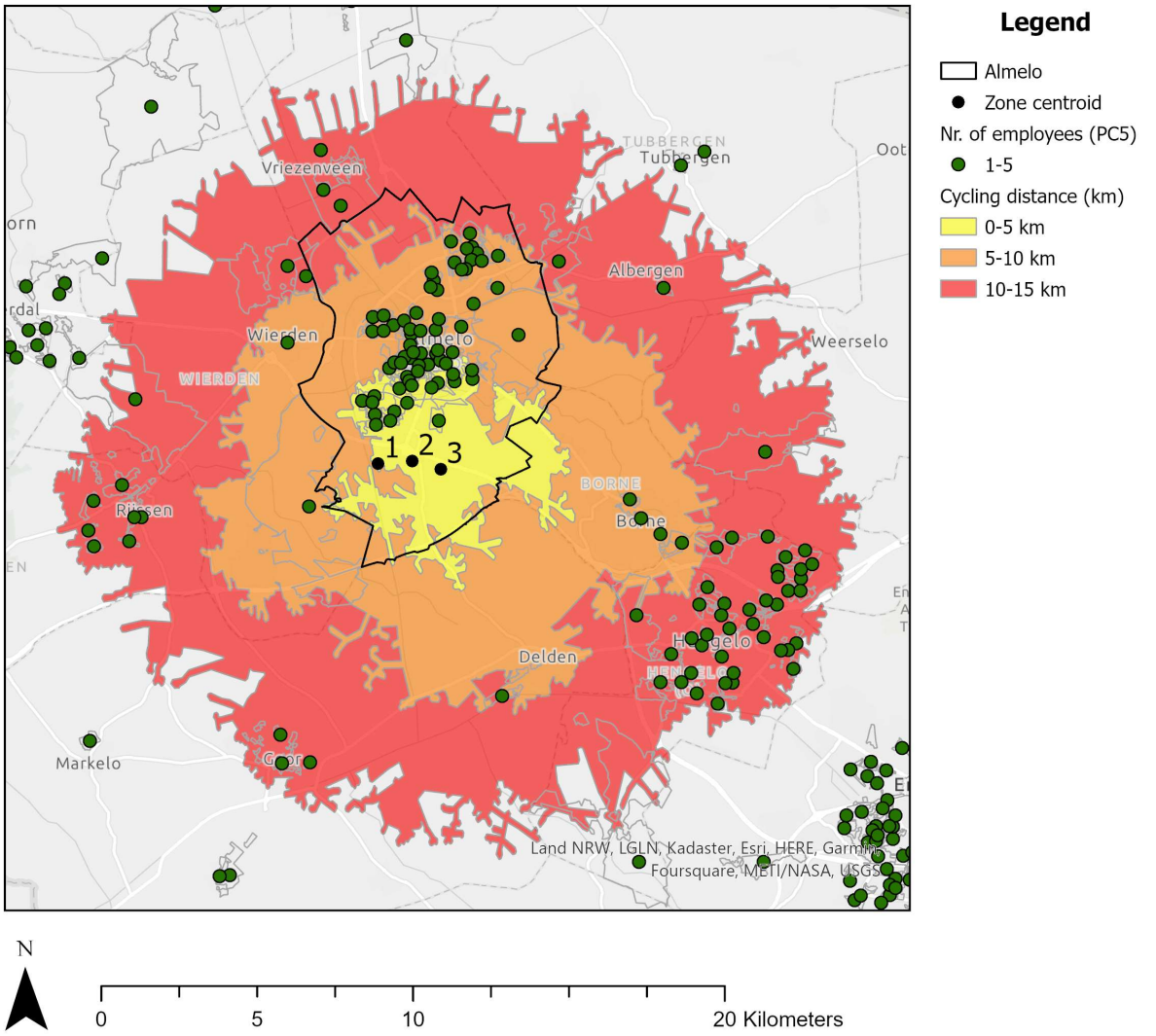

Figure 33: Bicycle accessibility isochrones of zone 3

B Public transport accessibility isochrones

With the use of the TravelTime API demo [16], accessibility isochrones have been created for the three zones at XL Businesspark. Each figure shows the area that can be reached from a specific zone at one of the arrival or departure times from Table 6 in Section 4.2.

B.1 Accessibility zone 1

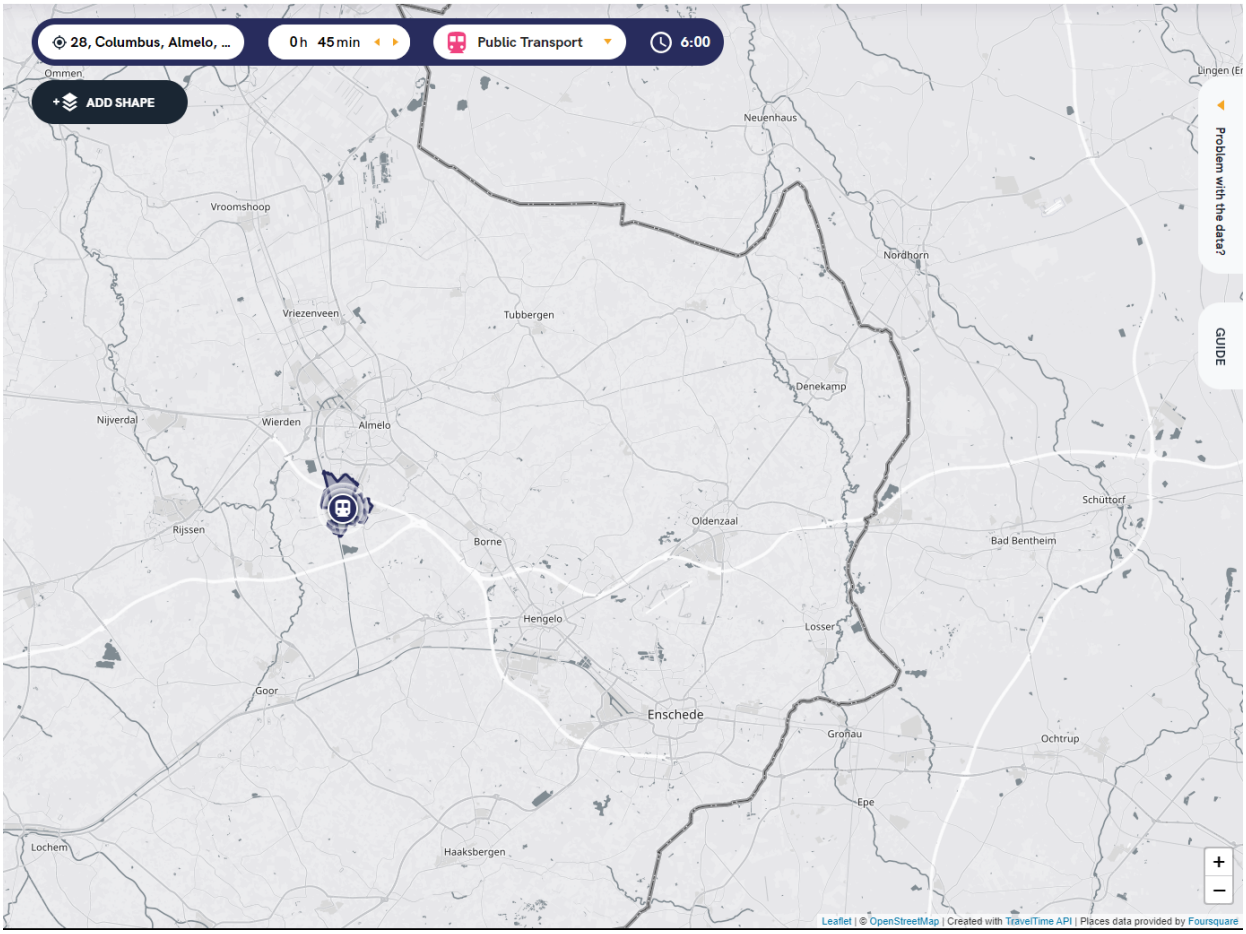

Figure 34: Zone 1, arrive at 06:00

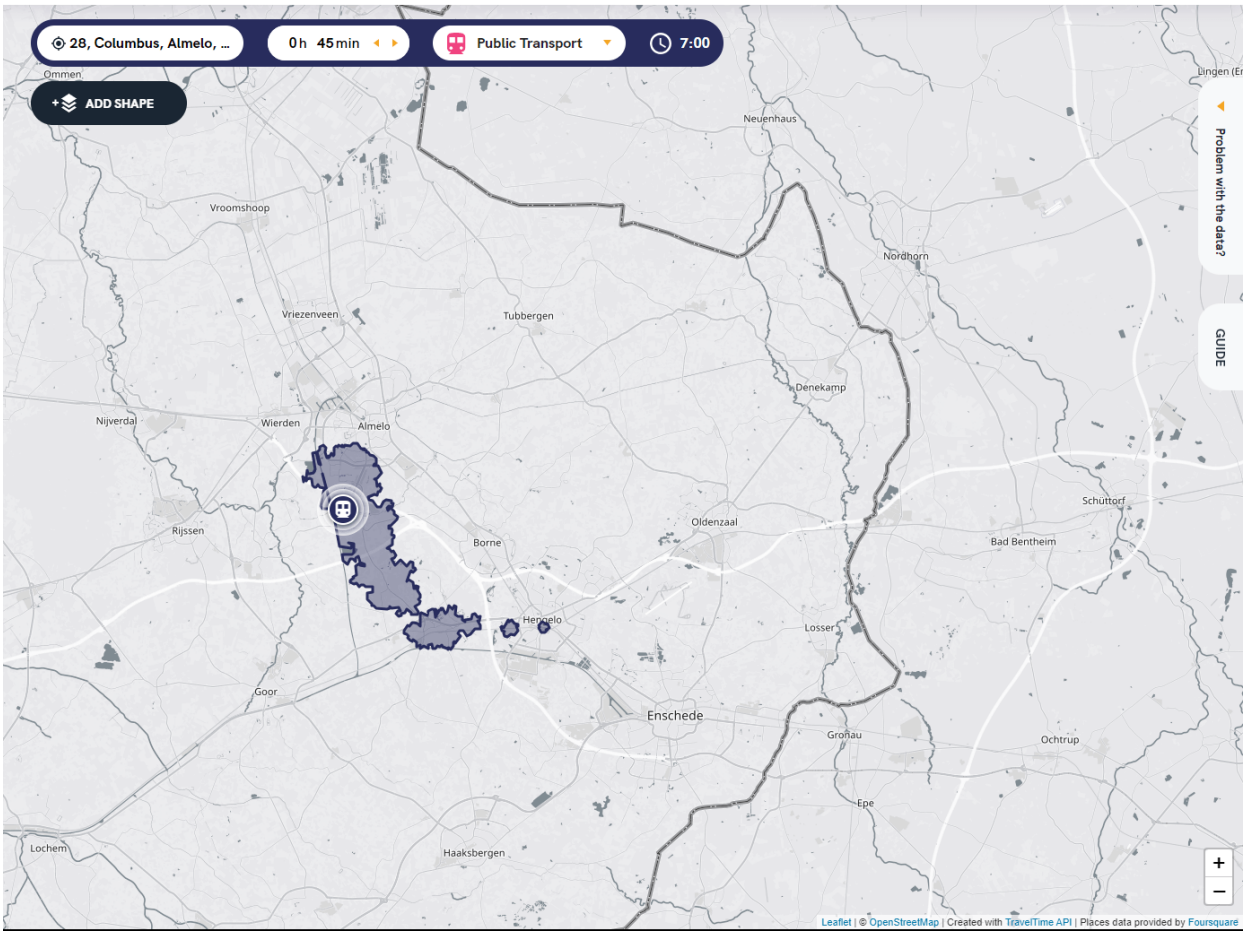

Figure 35: Zone 1, arrive at 07:00

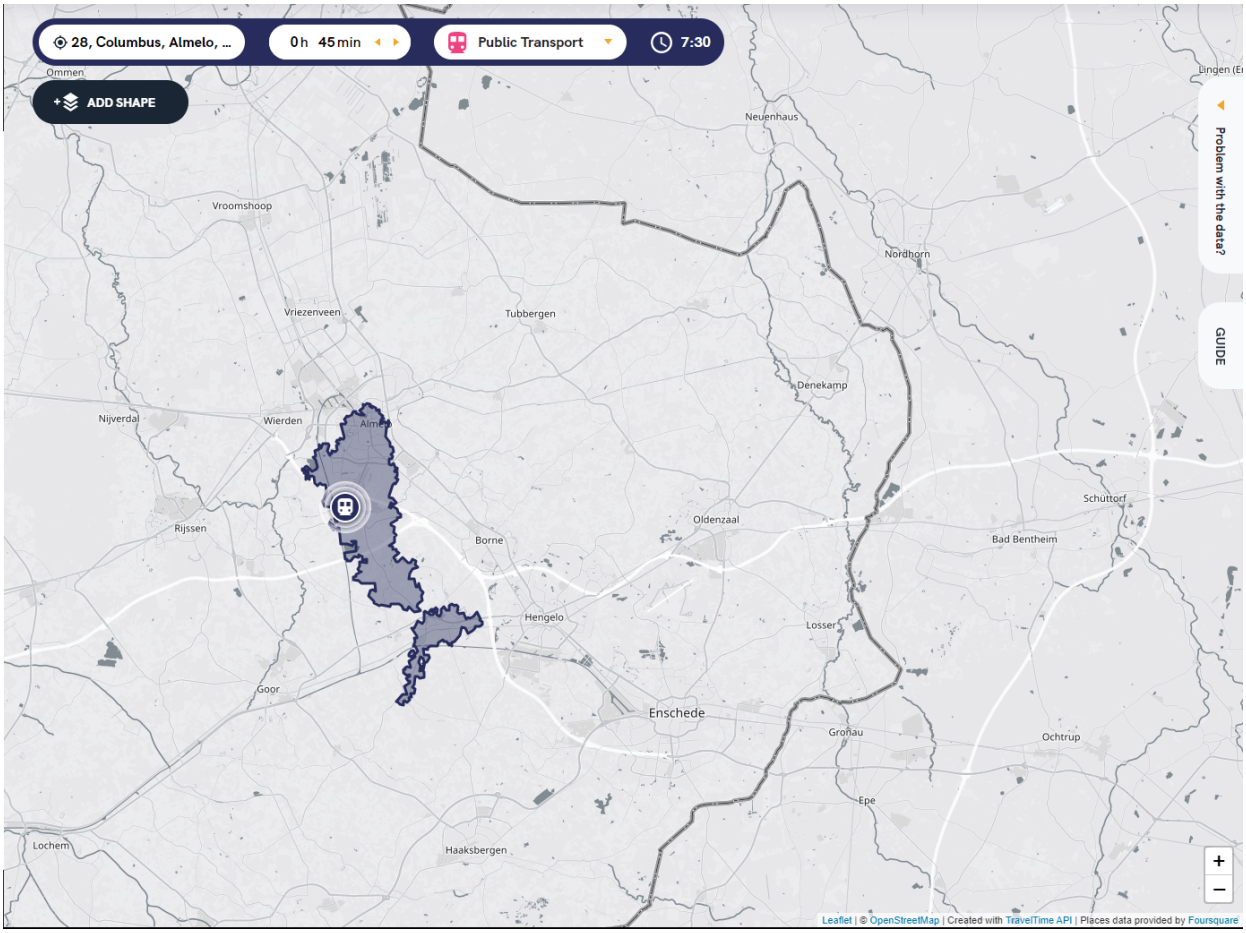

Figure 36: Zone 1, arrive at 07:30

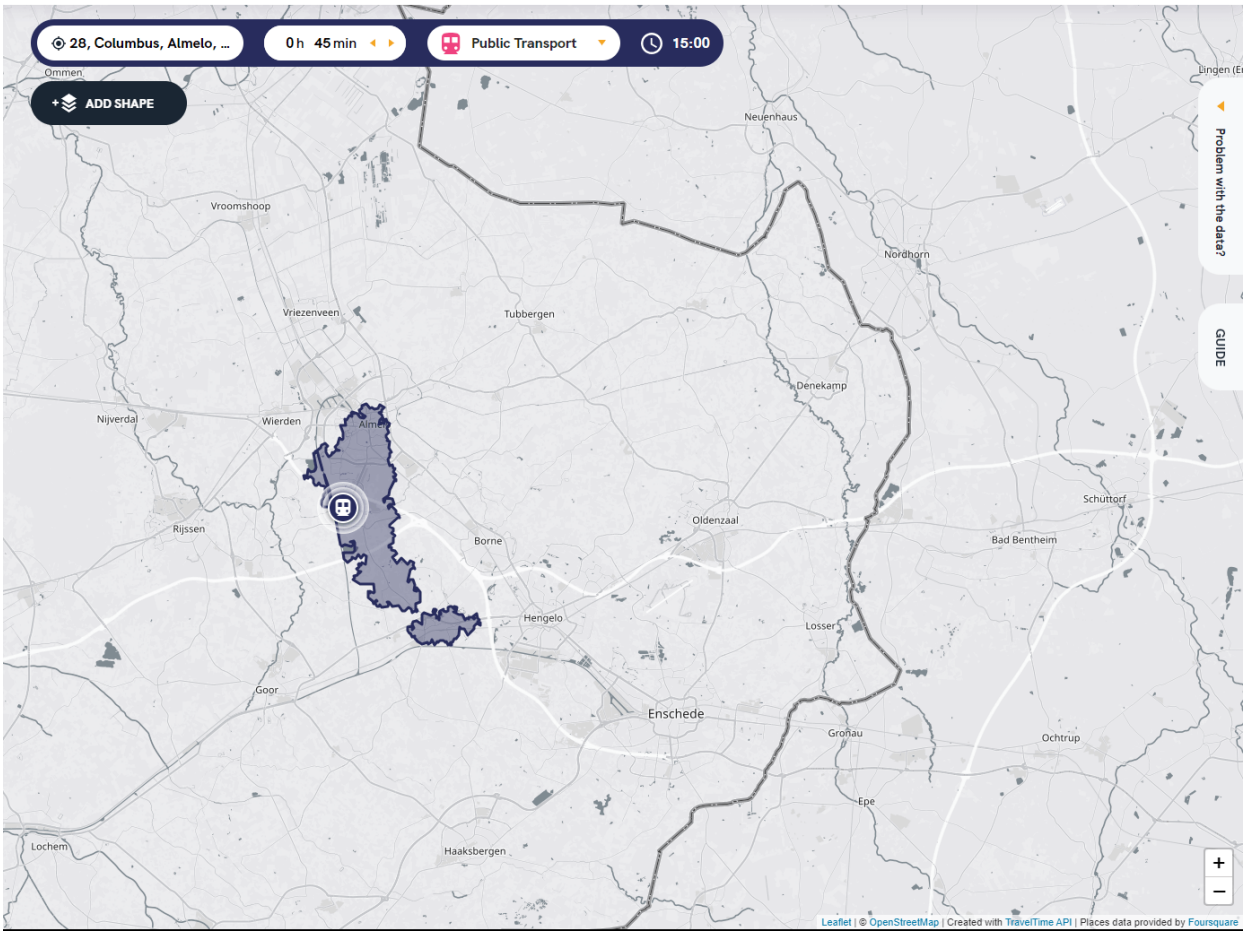

Figure 37: Zone 1, arrive at 15:00

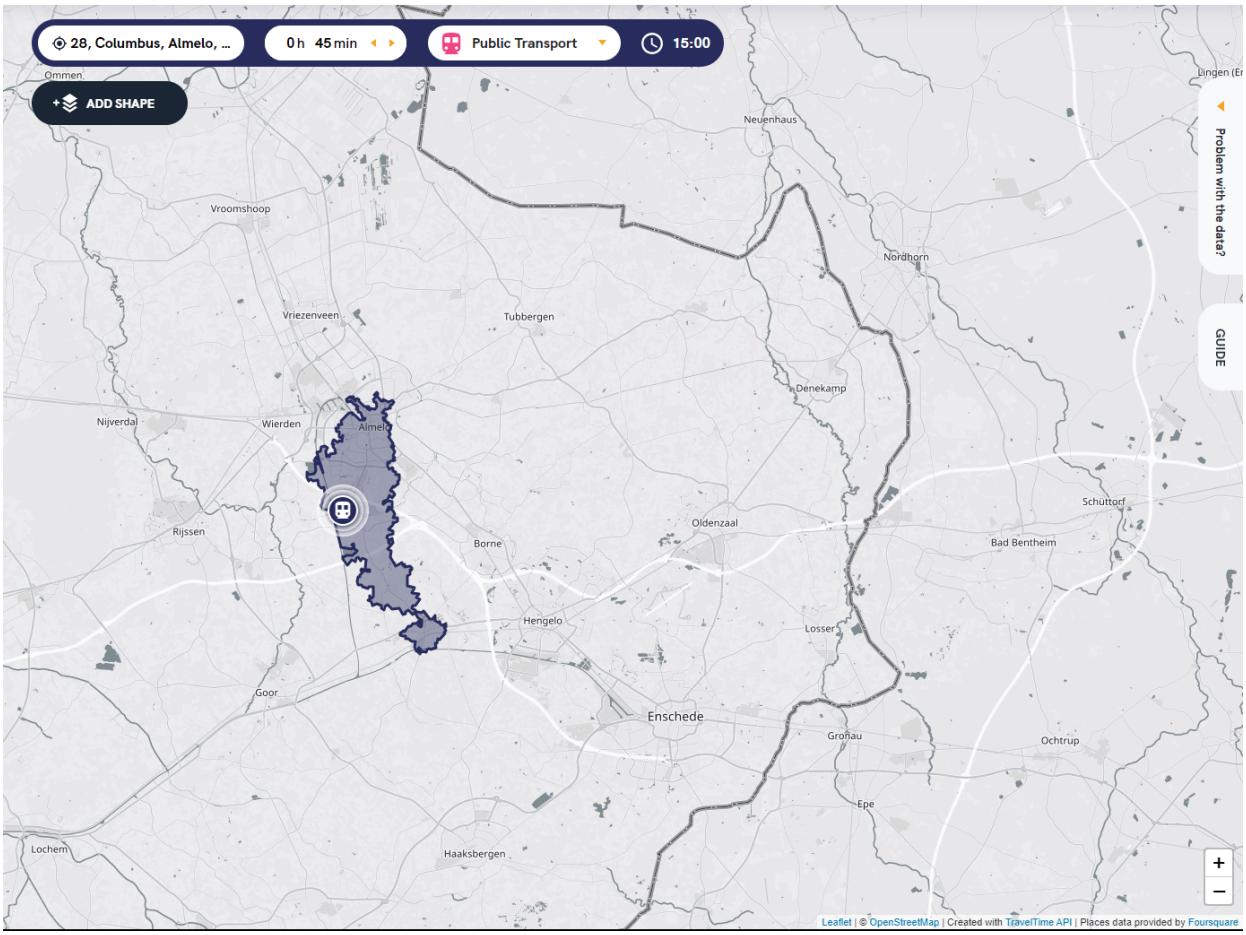

Figure 38: Zone 1, depart at 15:00

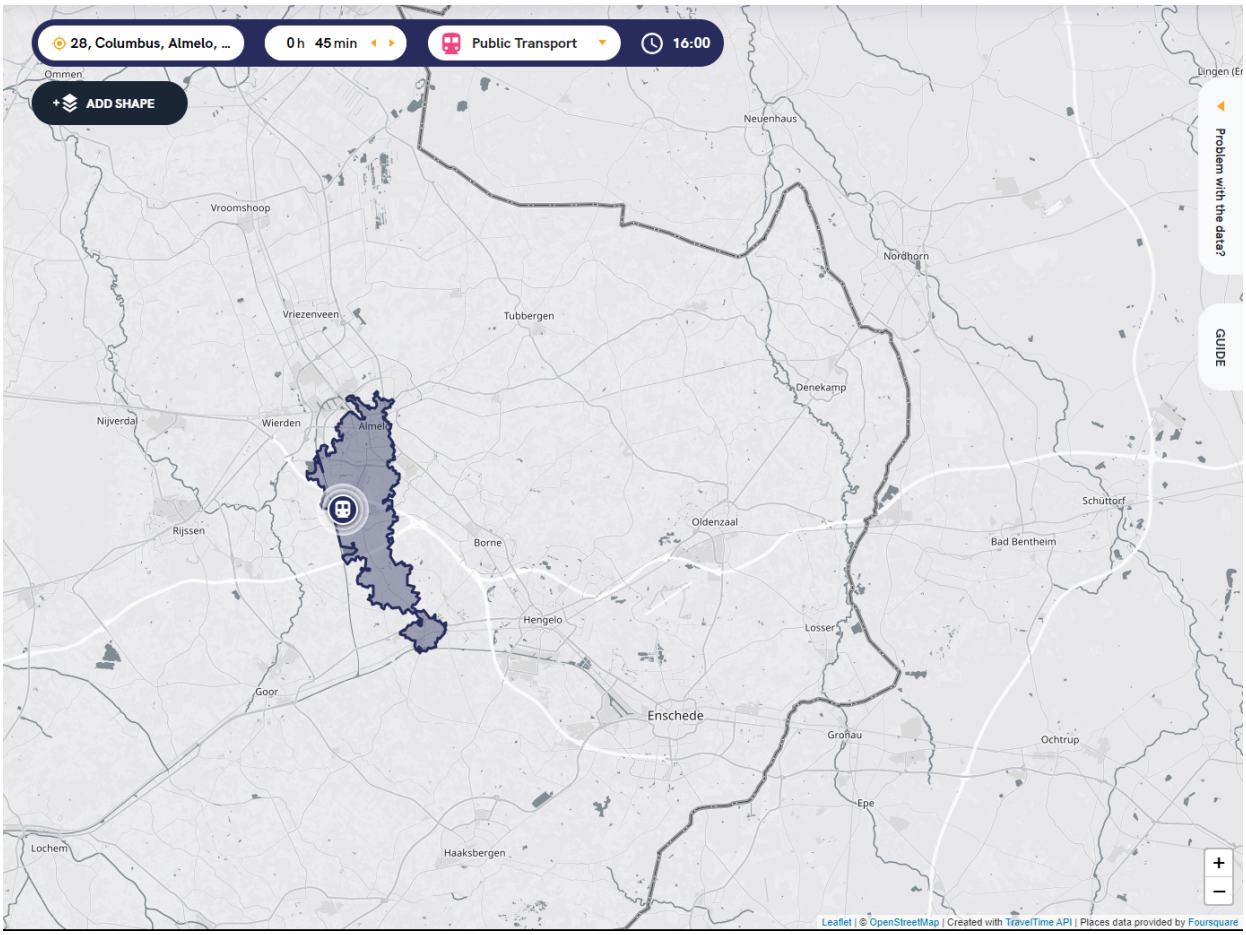

Figure 39: Zone 1, depart at 16:00

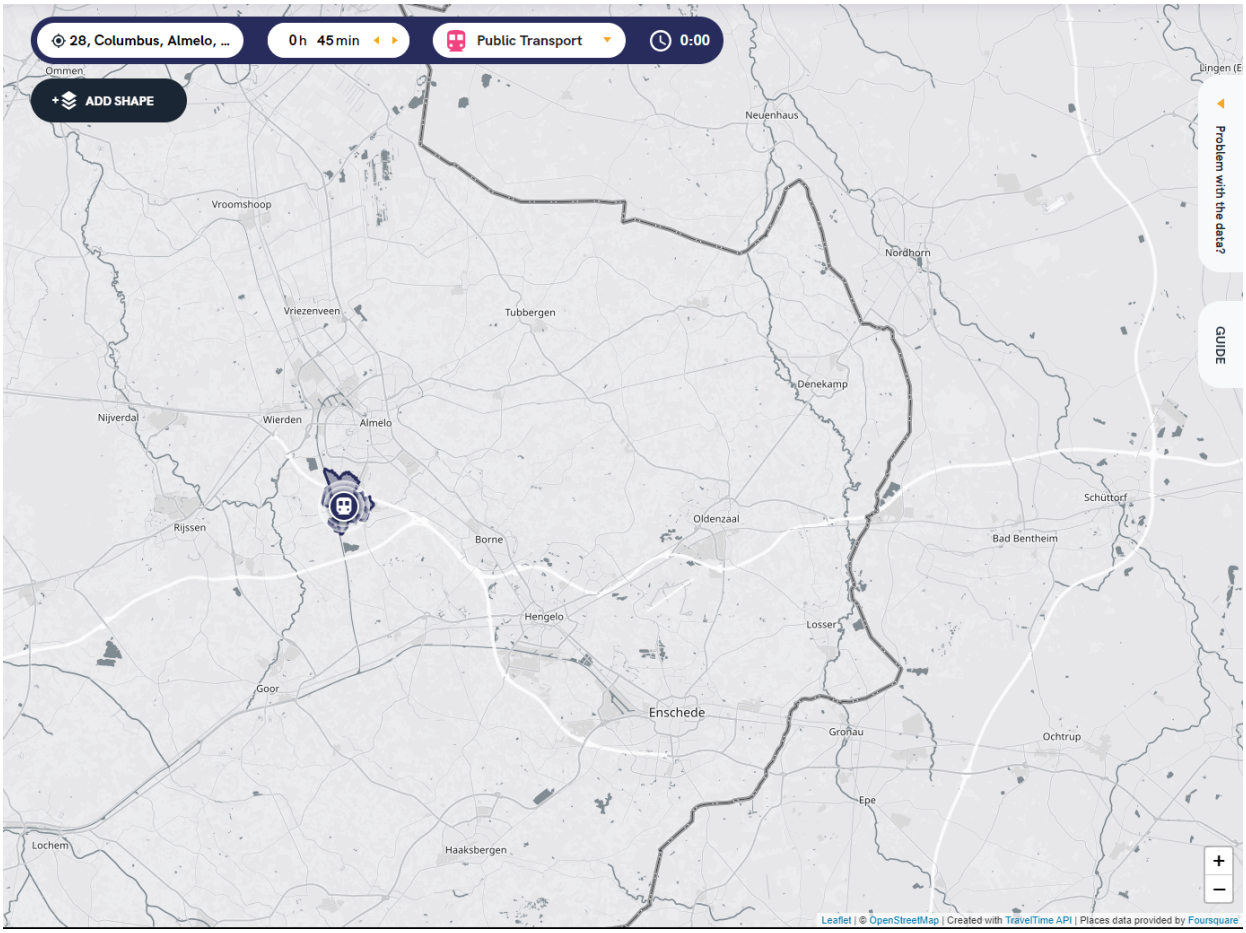

Figure 40: Zone 1, depart at 00:00

B.2 Accessibility zone 2

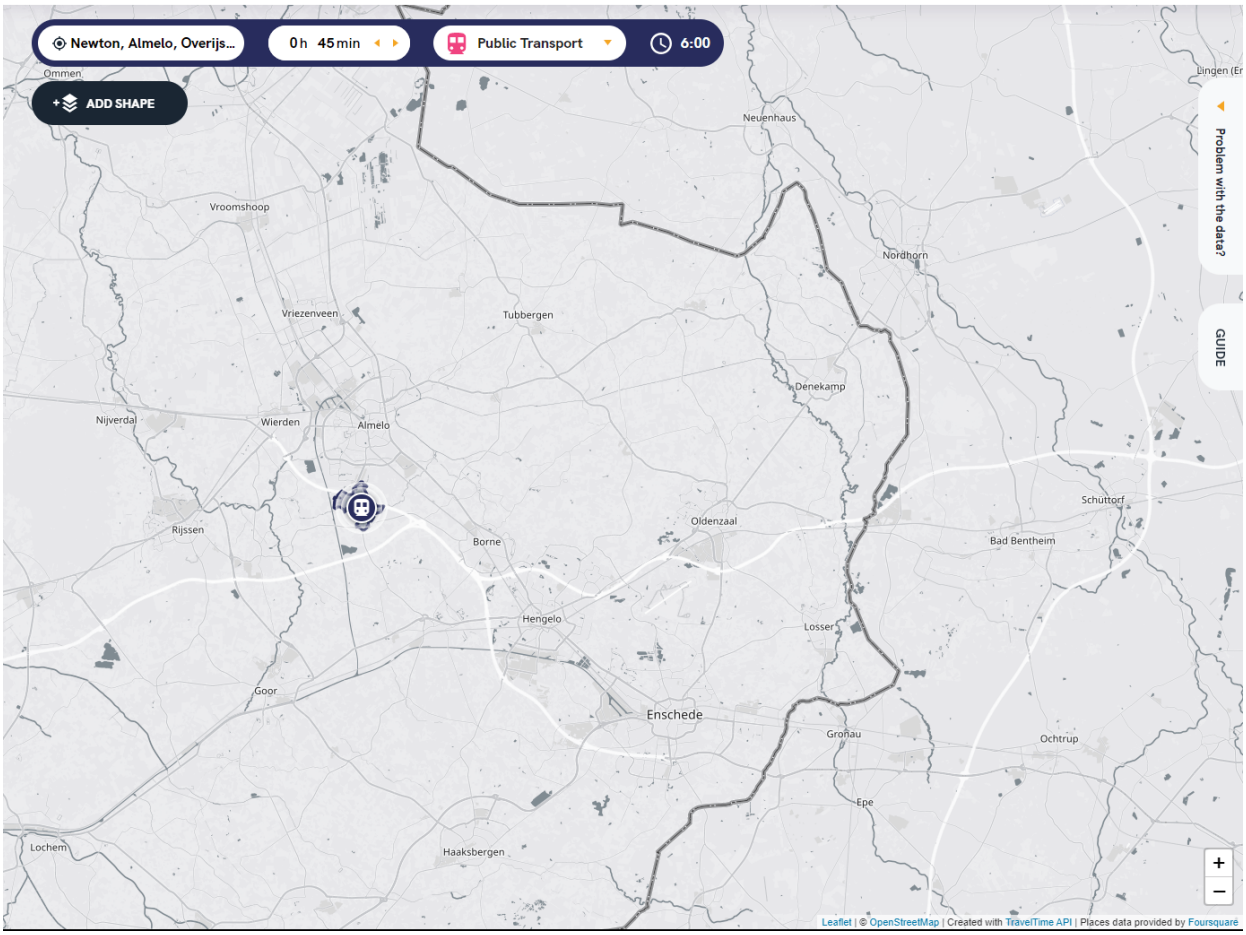

Figure 41: Zone 2, arrive at 06:00

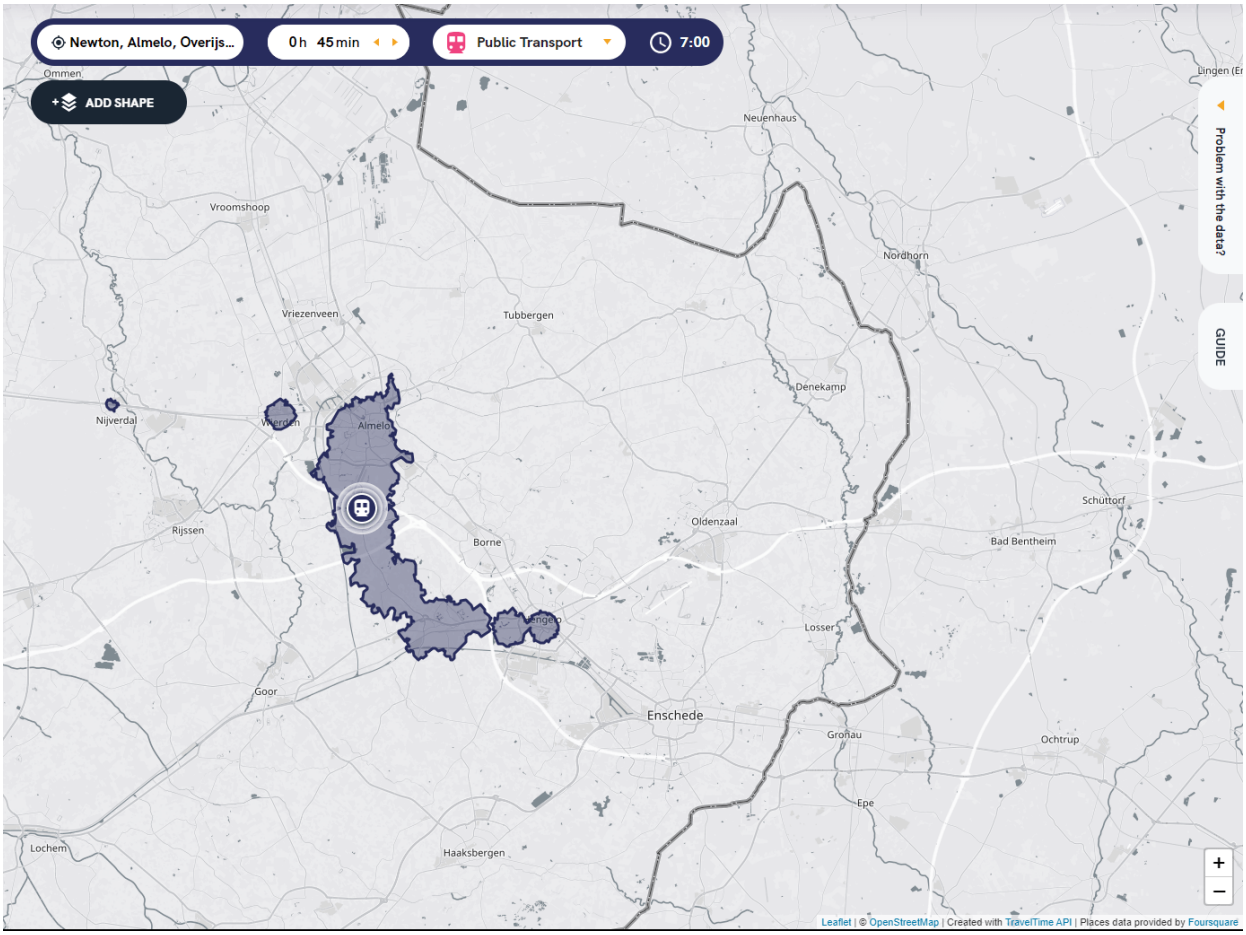

Figure 42: Zone 2, arrive at 07:00

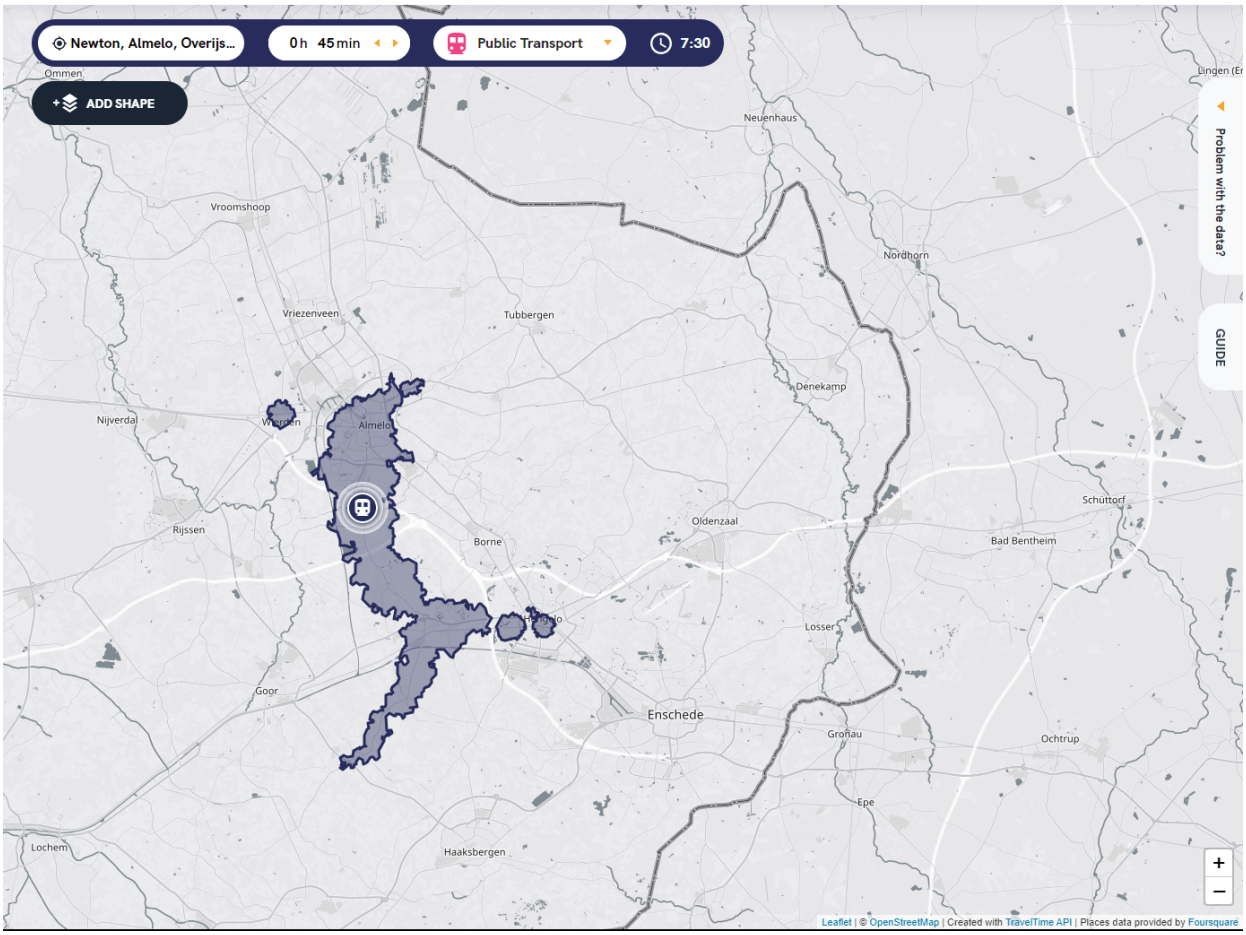

Figure 43: Zone 2, arrive at 07:30

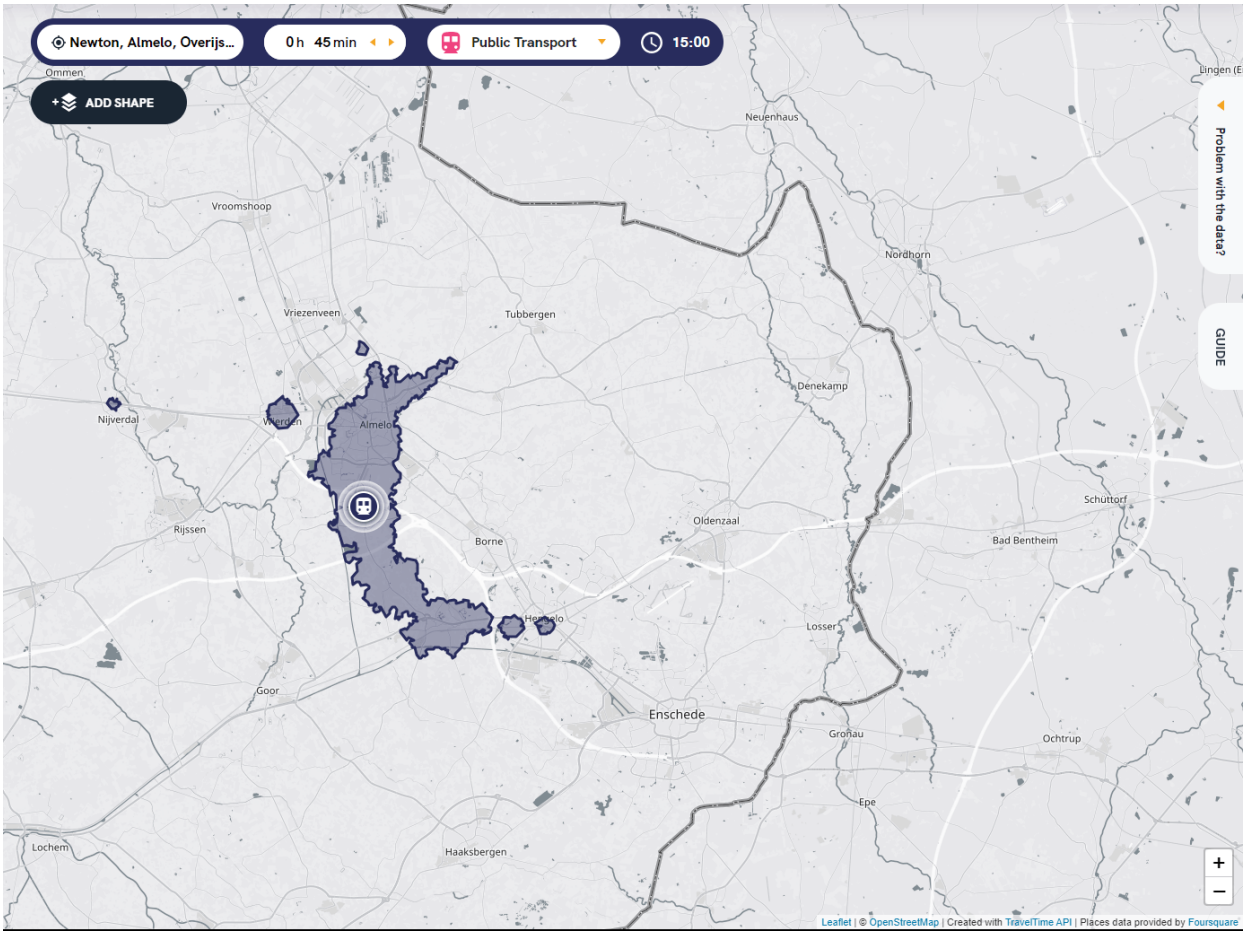

Figure 44: Zone 2, arrive at 15:00

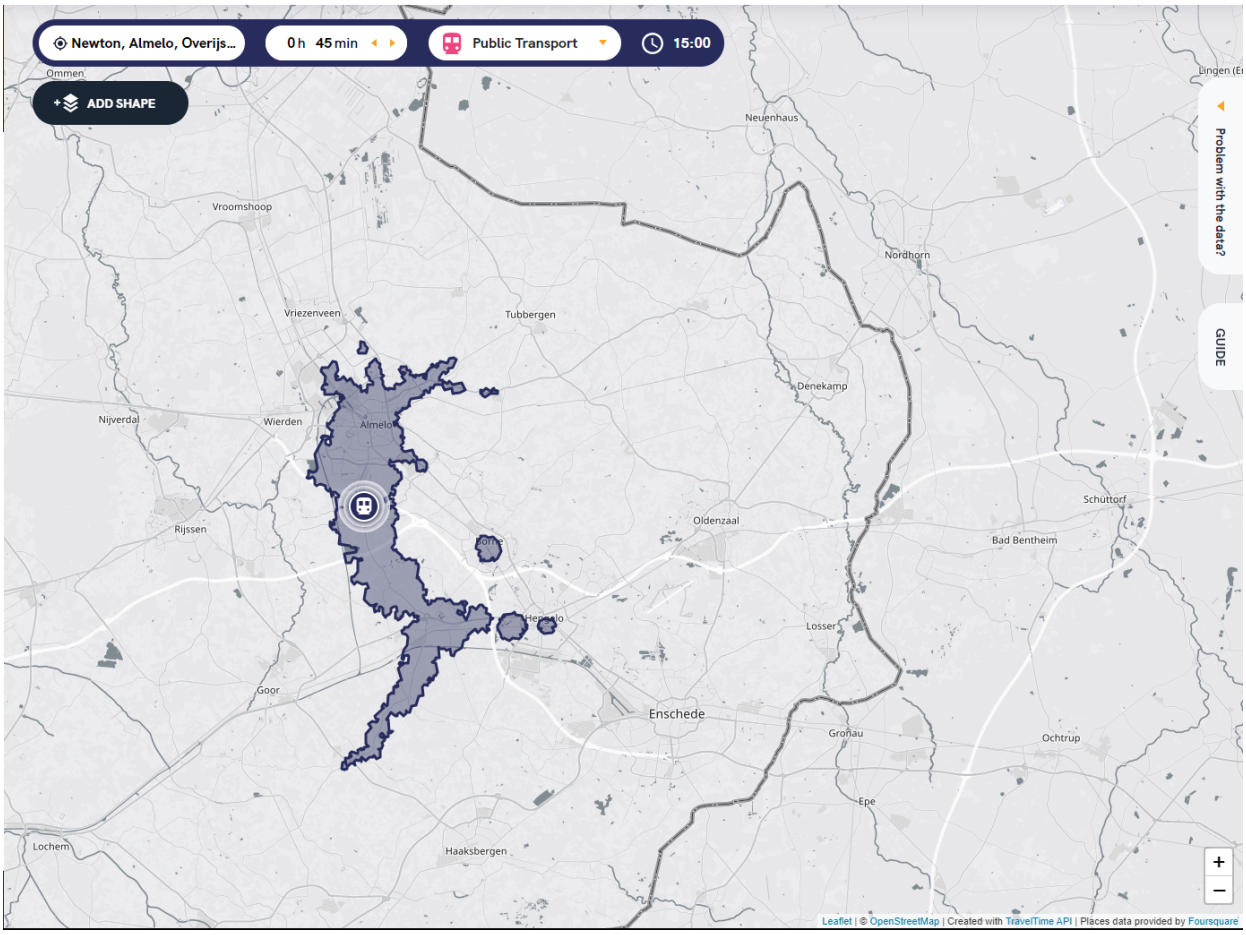

Figure 45: Zone 2, depart at 15:00

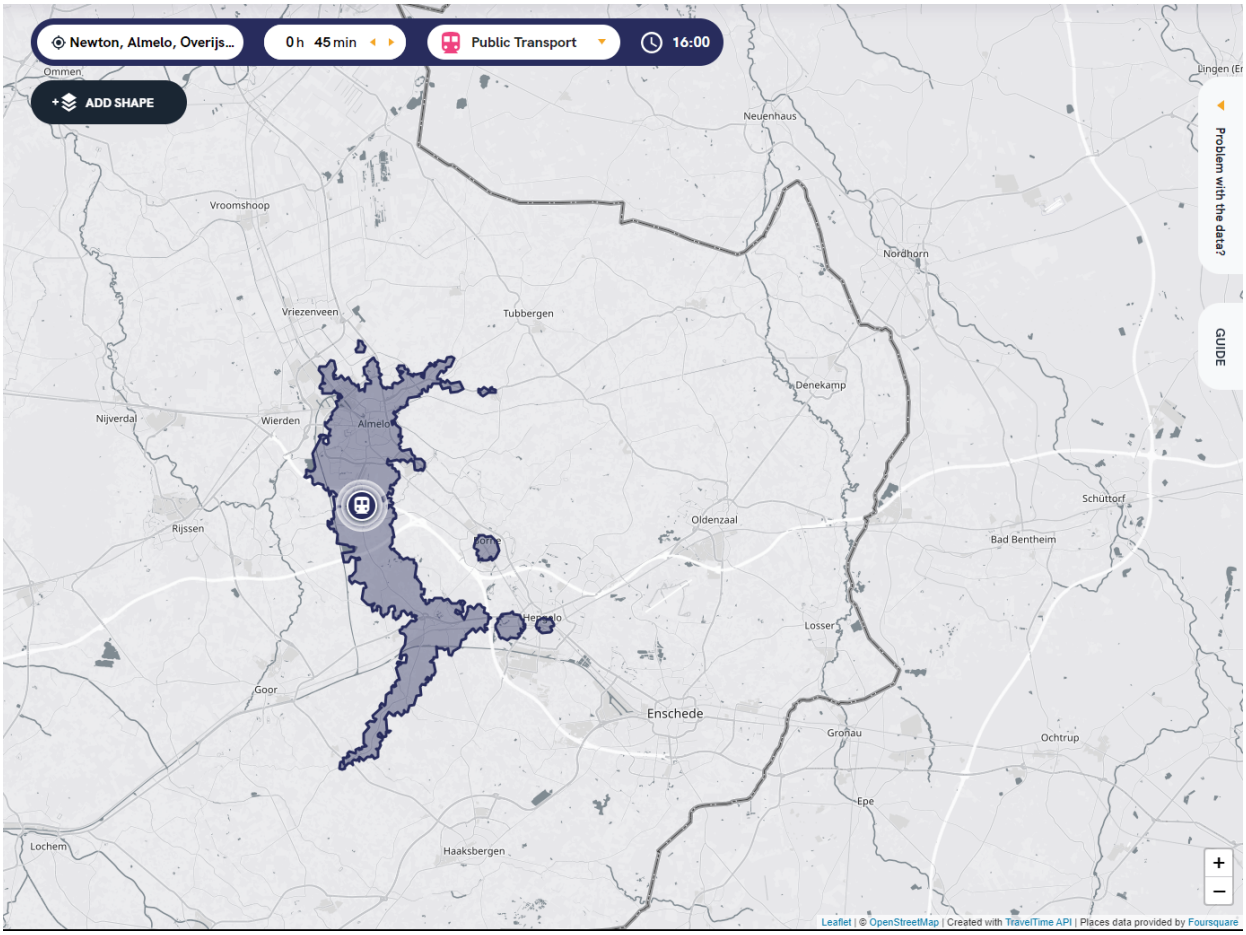

Figure 46: Zone 2, depart at 16:00

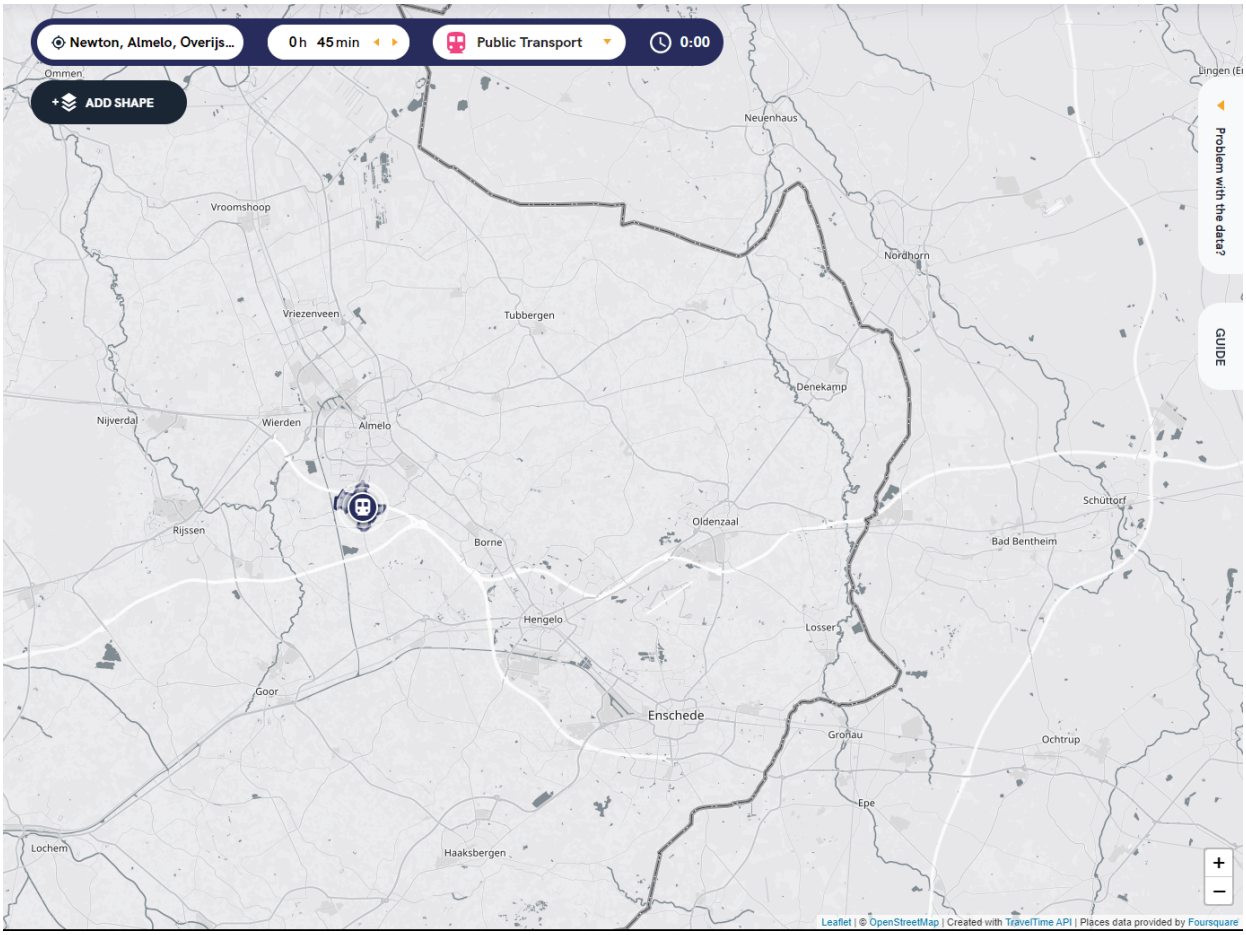

Figure 47: Zone 2, depart at 00:00

B.3 Accessibility zone 3

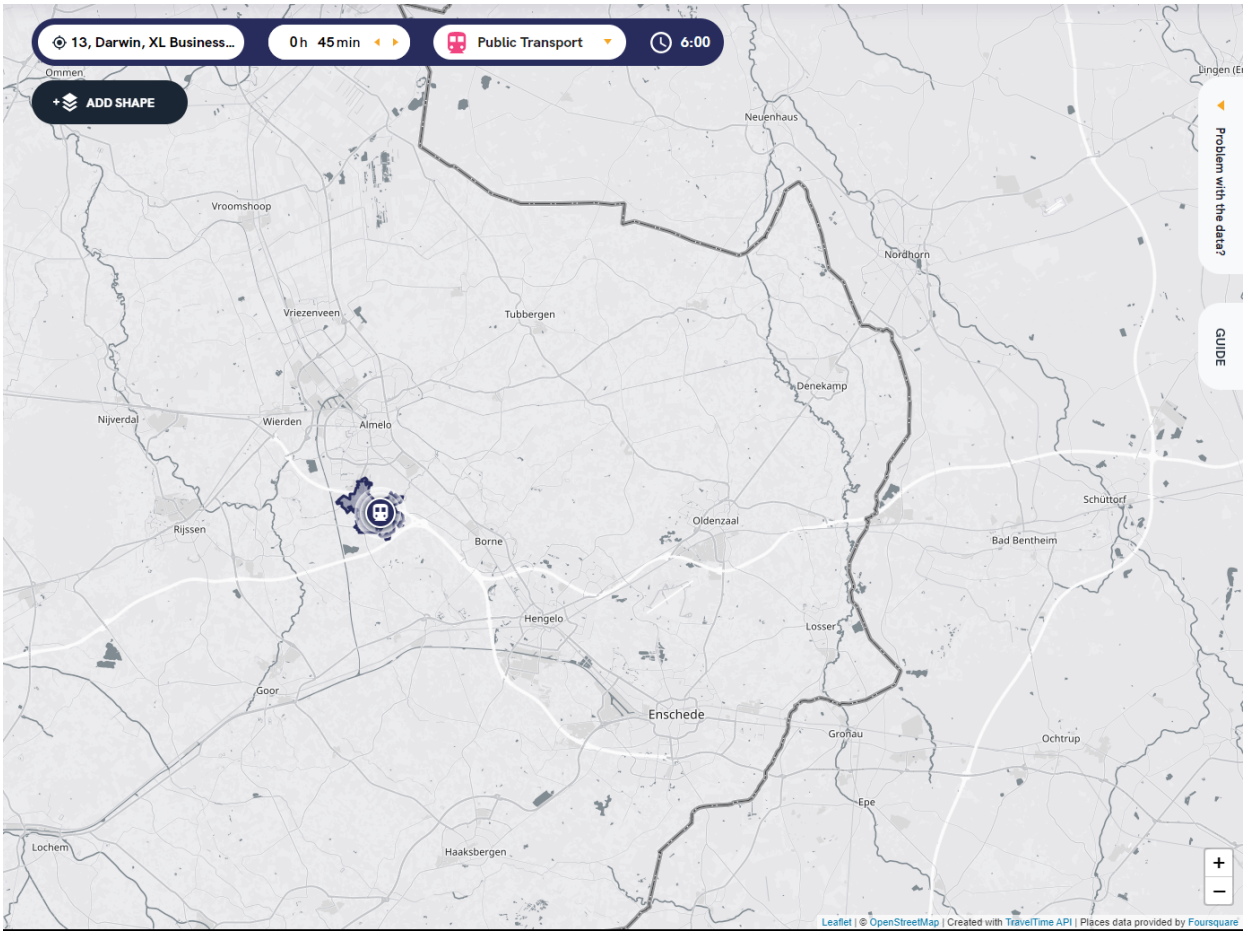

Figure 48: Zone 3, arrive at 06:00

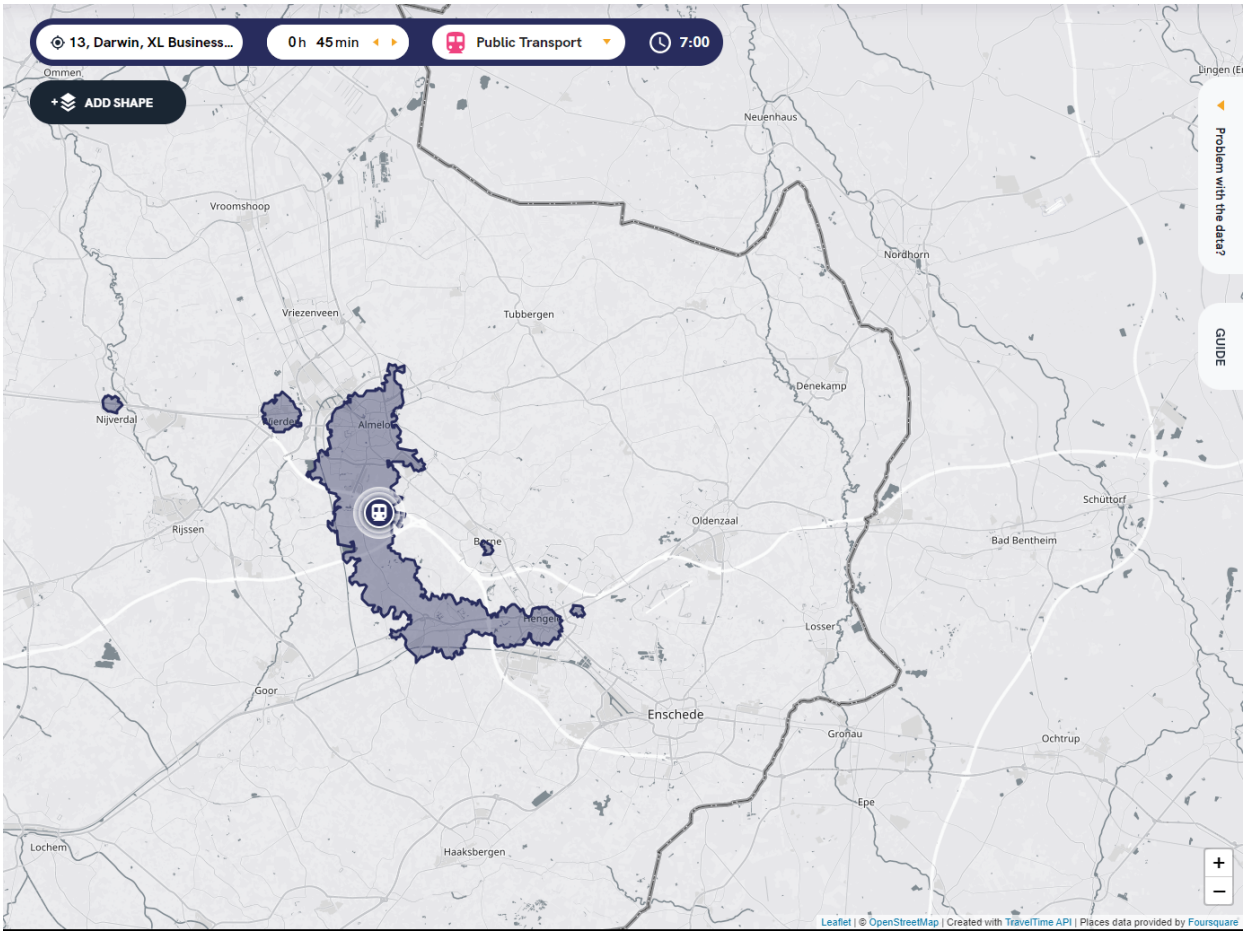

Figure 49: Zone 3, arrive at 07:00

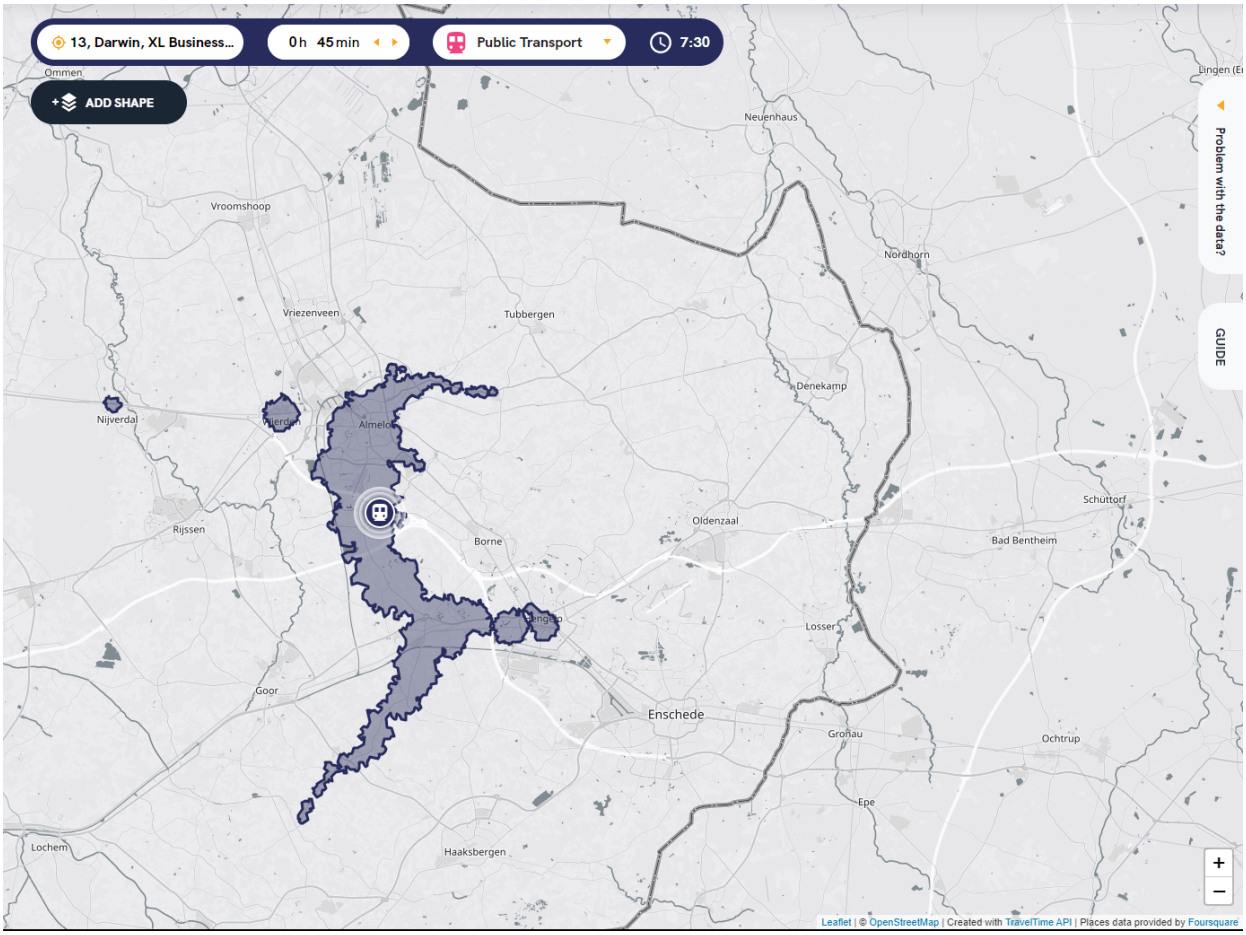

Figure 50: Zone 3, arrive at 07:30

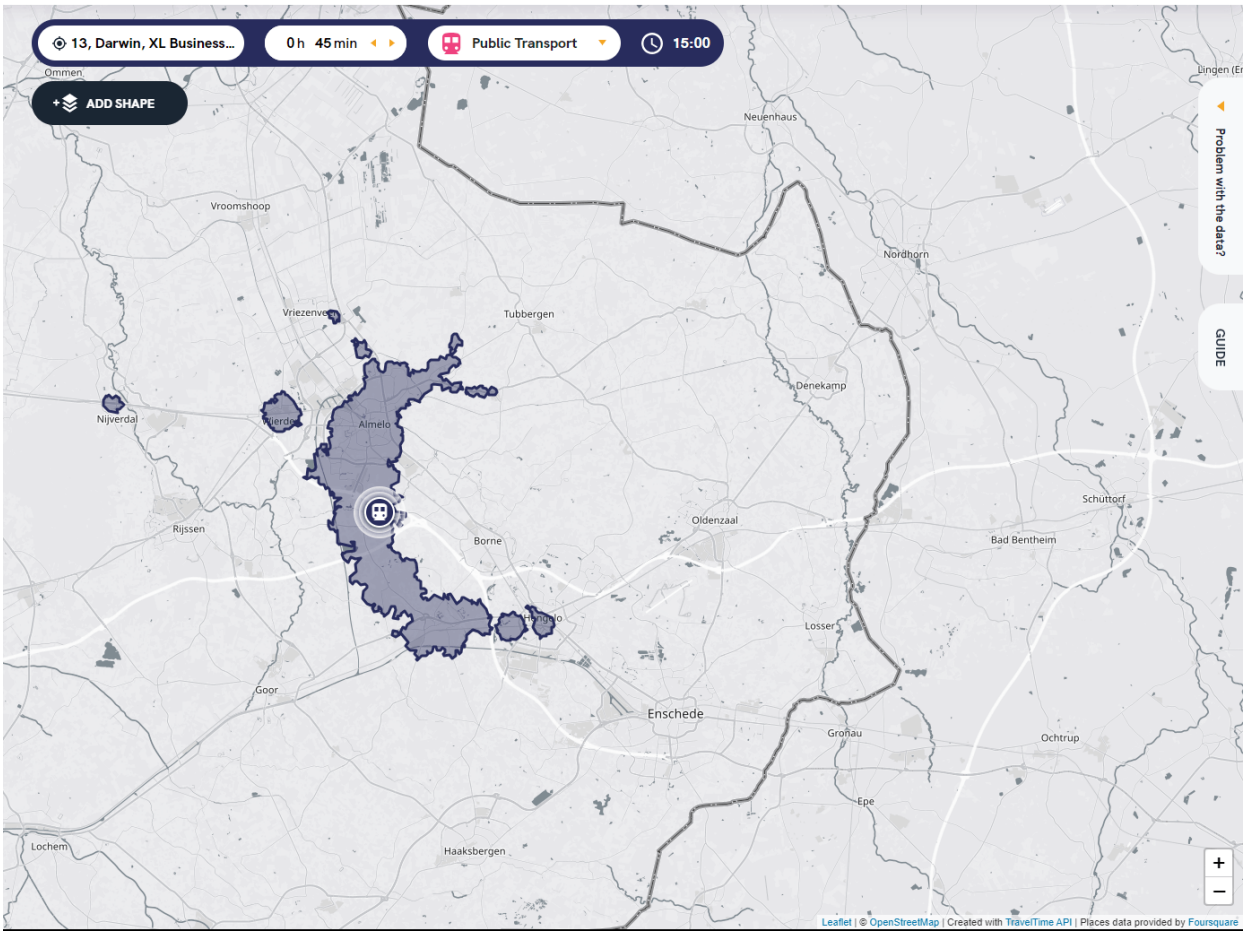

Figure 51: Zone 3, arrive at 15:00

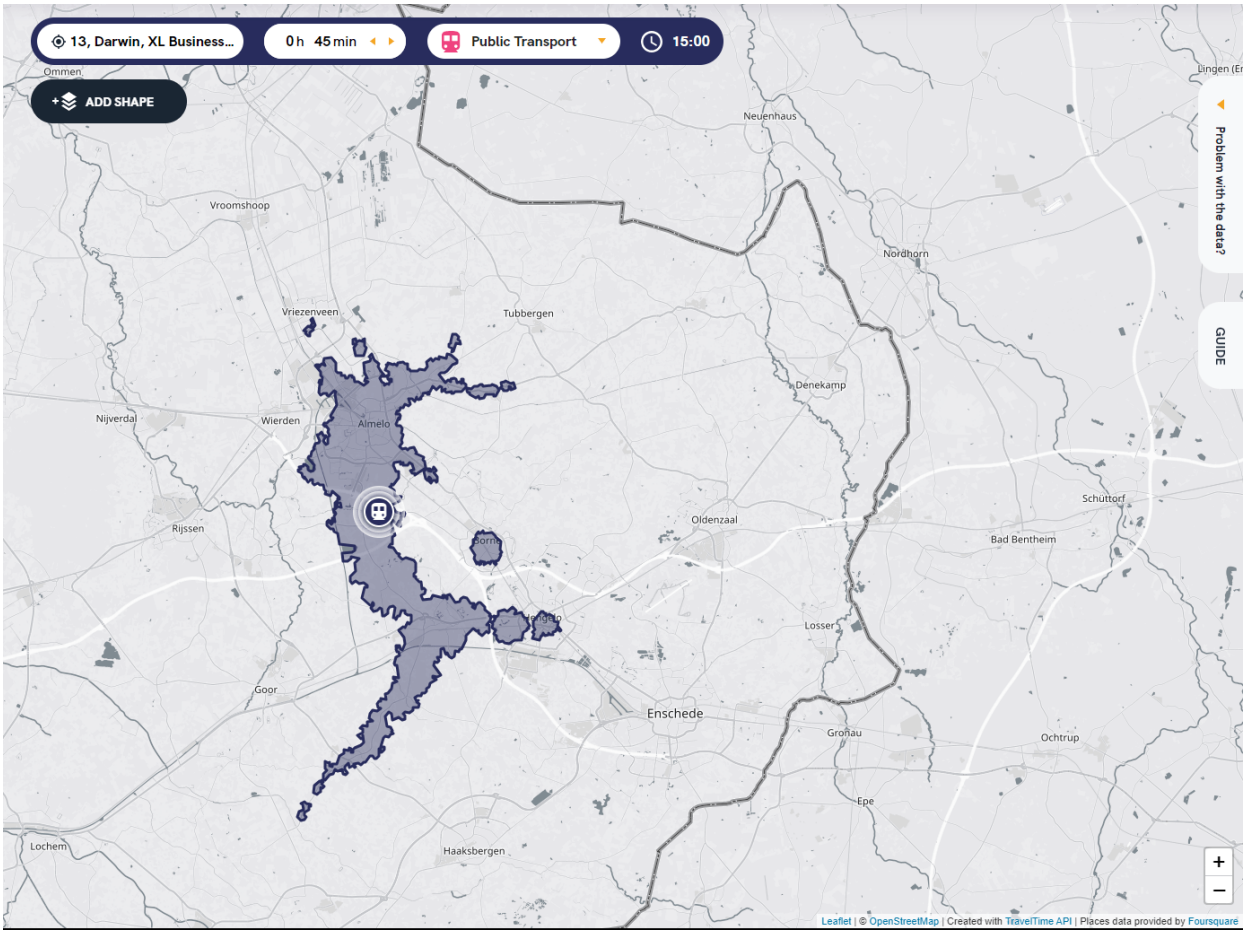

Figure 52: Zone 3, depart at 15:00

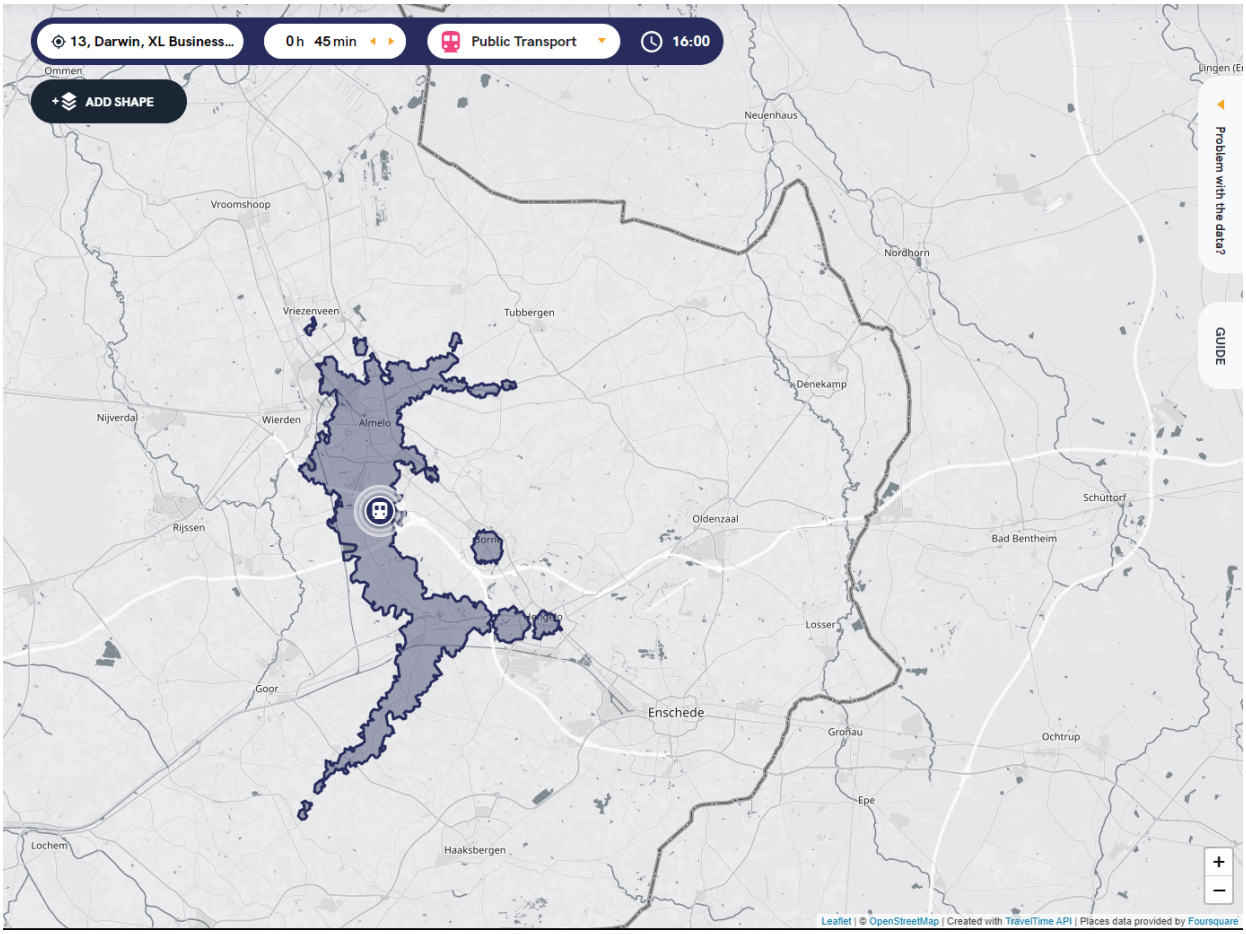

Figure 53: Zone 3, depart at 16:00

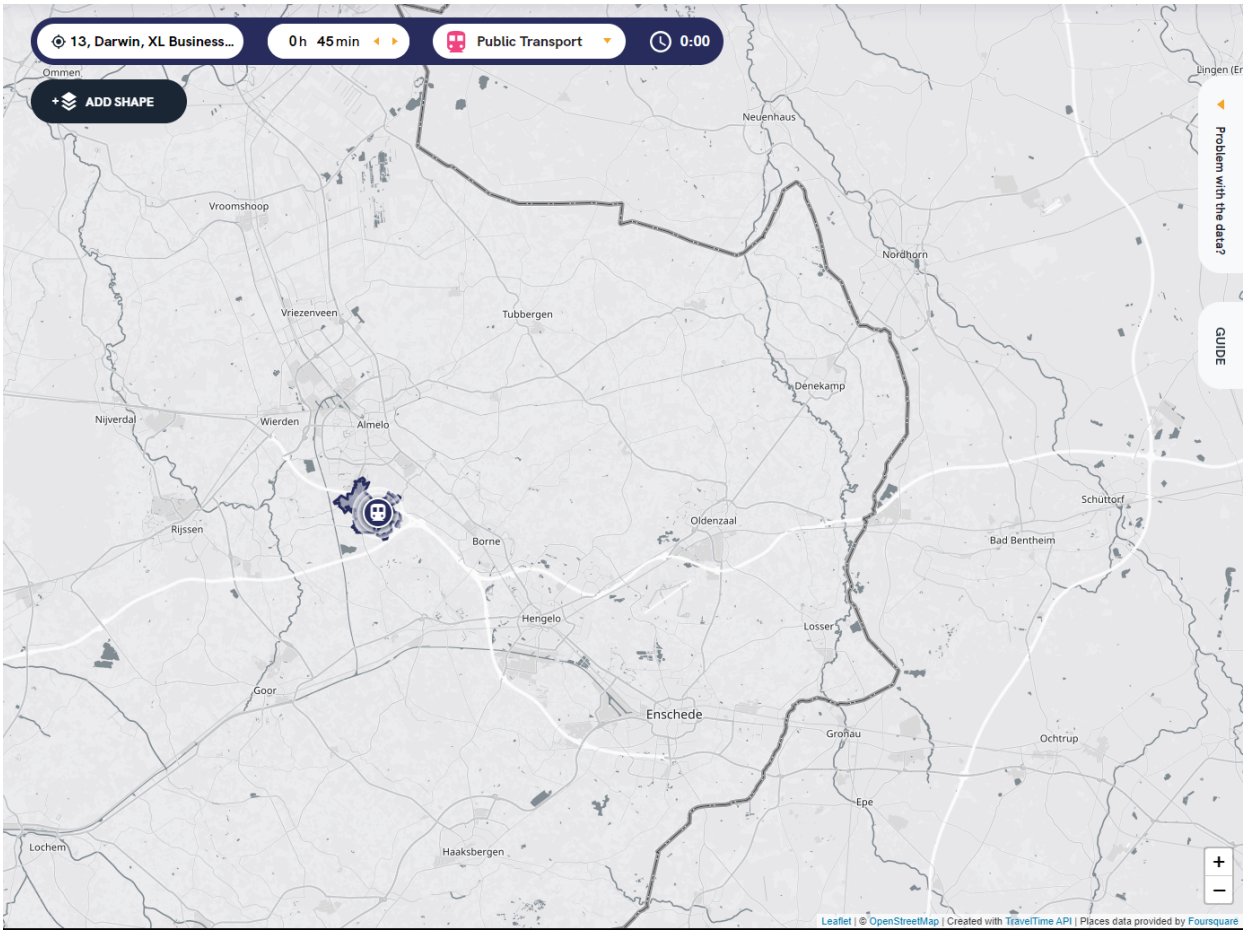

Figure 54: Zone 3, depart at 00:00

C Accessibility public transport stops

XL Businesspark has its own bus stop on the Pastoor Ossestraat. The figures in this appendix show the travel time to or from several bus stops and train stations to or from the bus stop at the Pastoor Ossestraat. The stops are located on line 66 and lines that can be reached with one transfer. The colors of the stops represent the time that it takes to reach that stop. The travel time that the colors represent are the same as the car travel time isochrones in Figure 11 and Figure 12 with a travel time ratio of 1,5 applied.

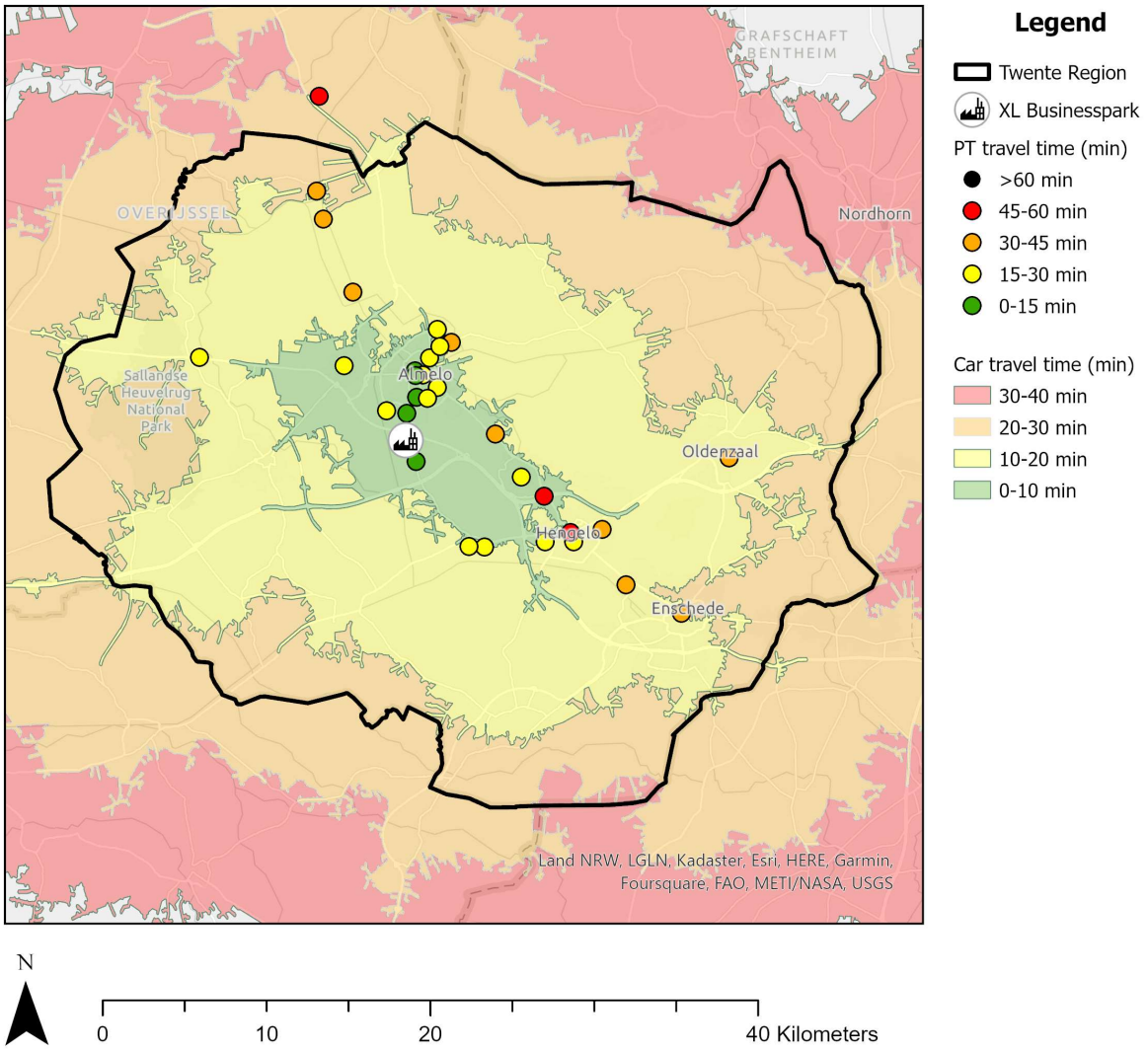

Figure 55: Arrival at bus stop XL Businesspark at 06:45

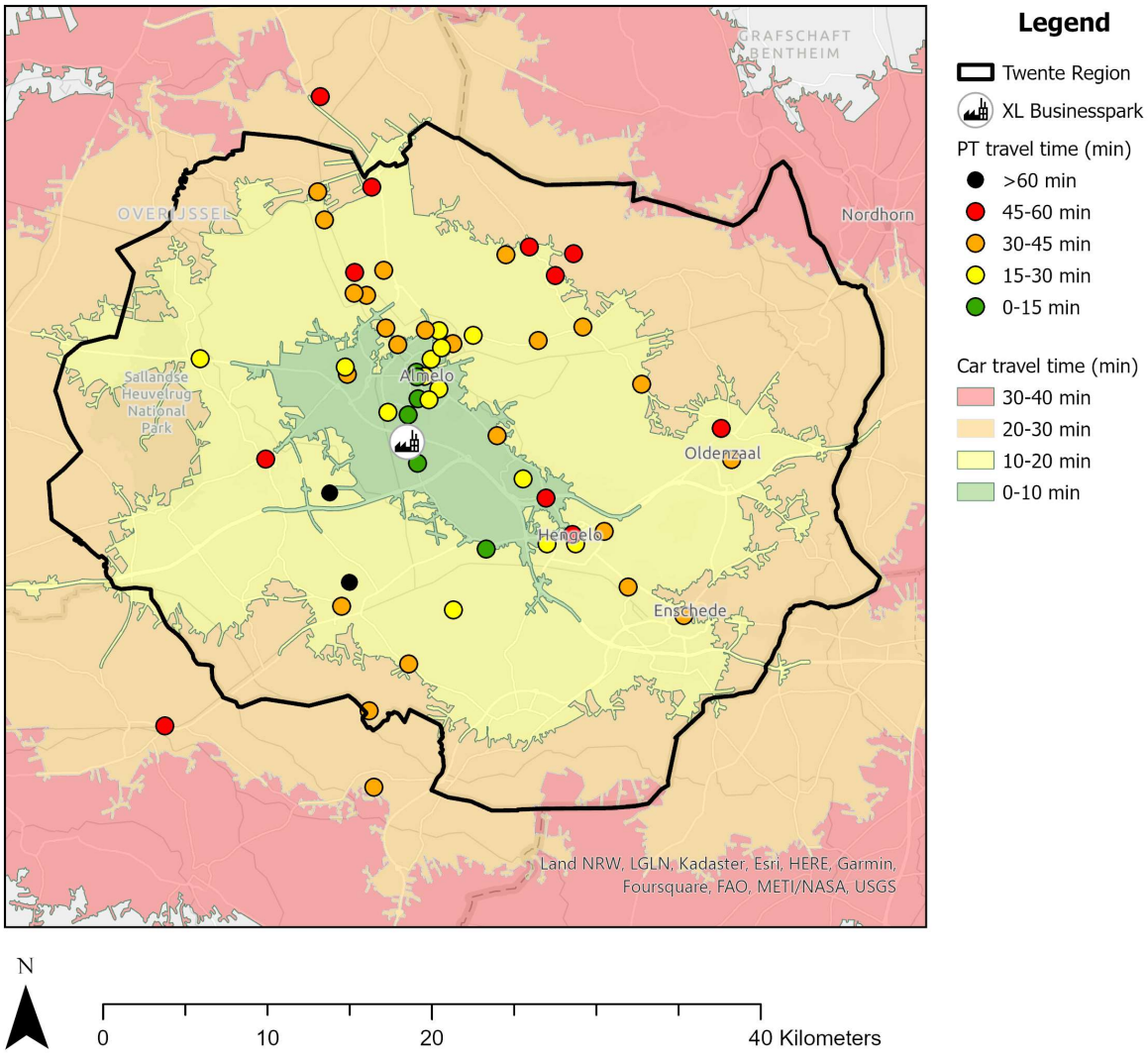

Figure 56: Arrival at bus stop XL Businesspark at 07:15

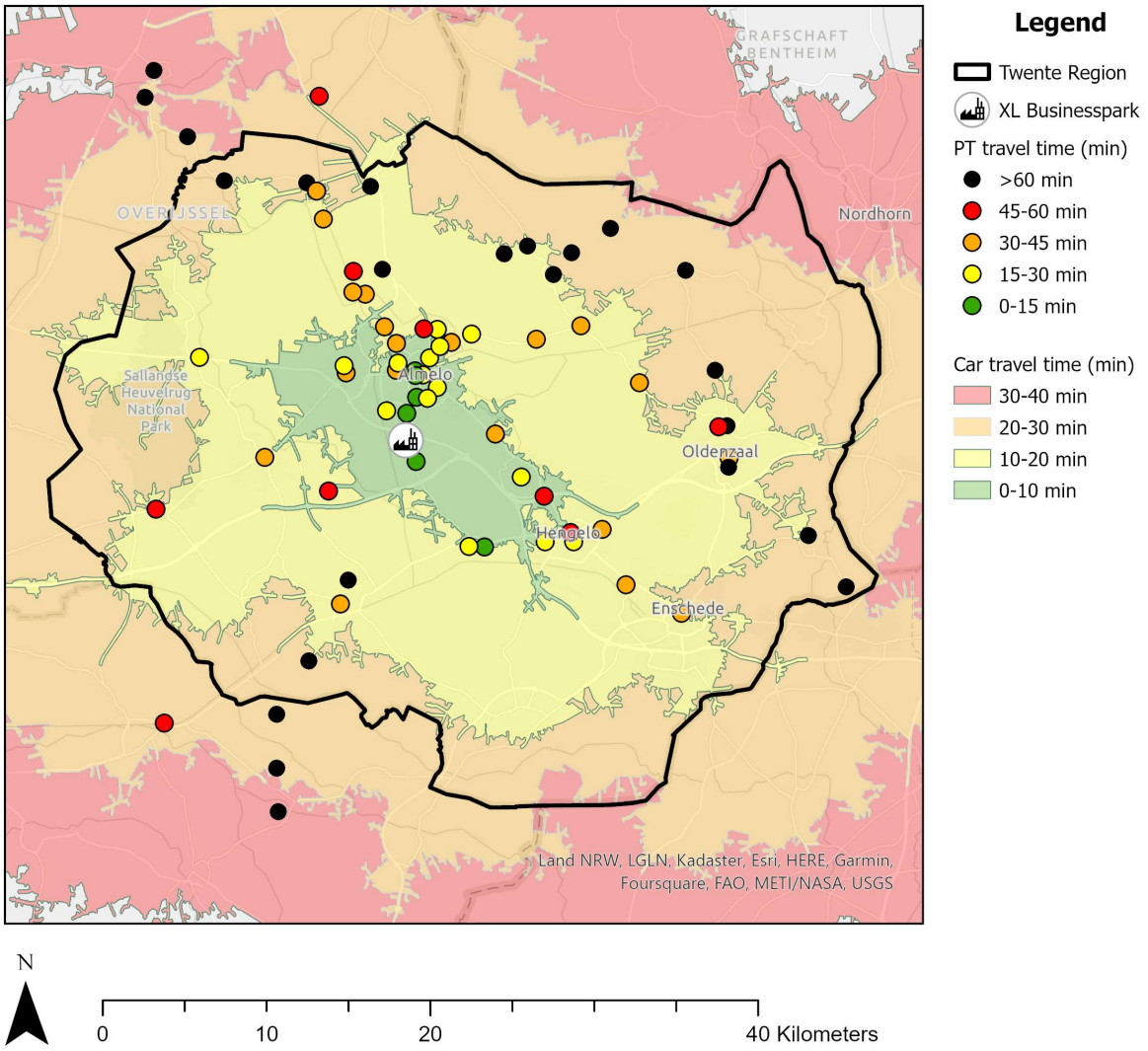

Figure 57: Arrival at bus stop XL Businesspark at 14:15

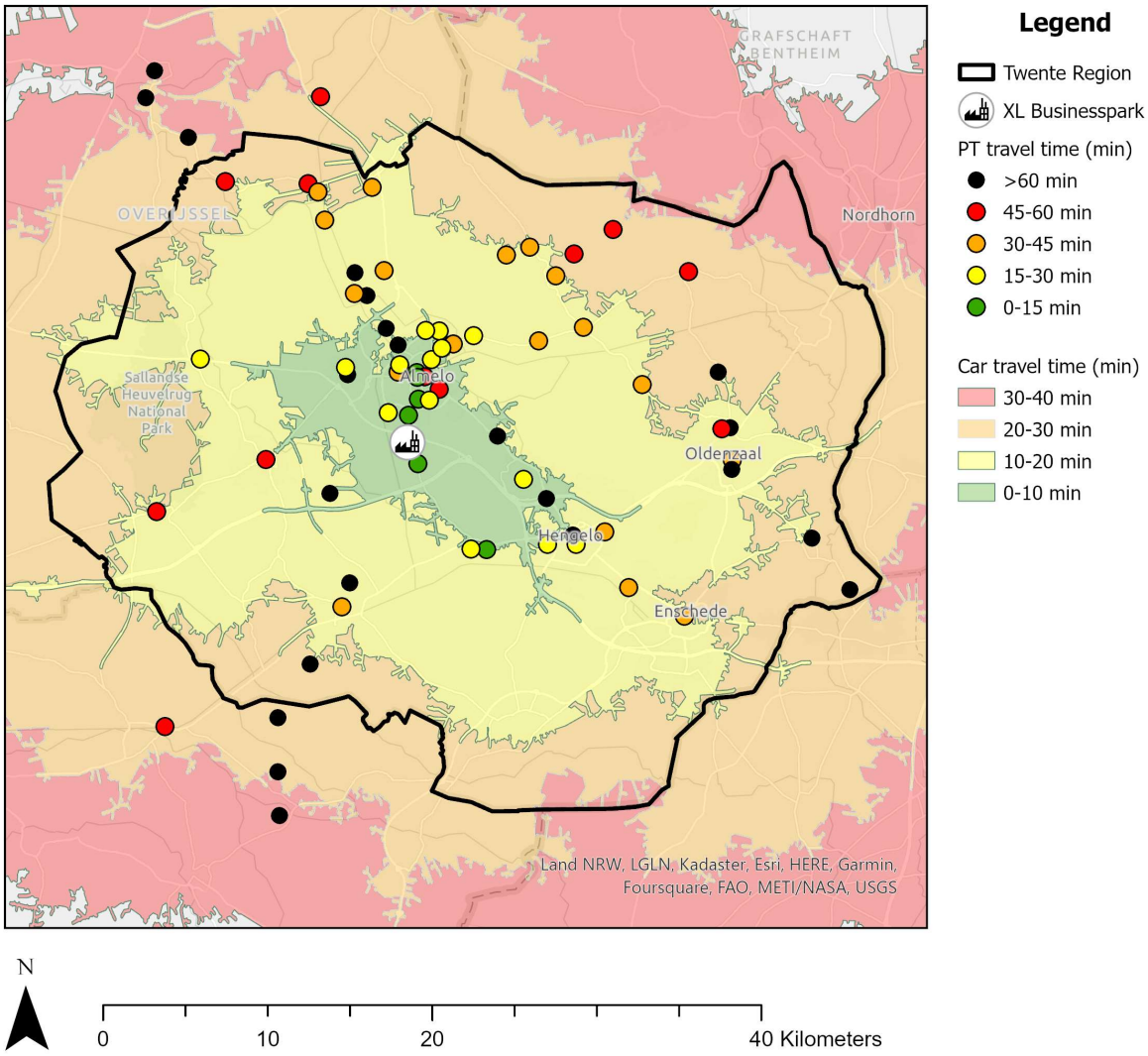

Figure 58: Arrival at bus stop XL Businesspark at 14:45

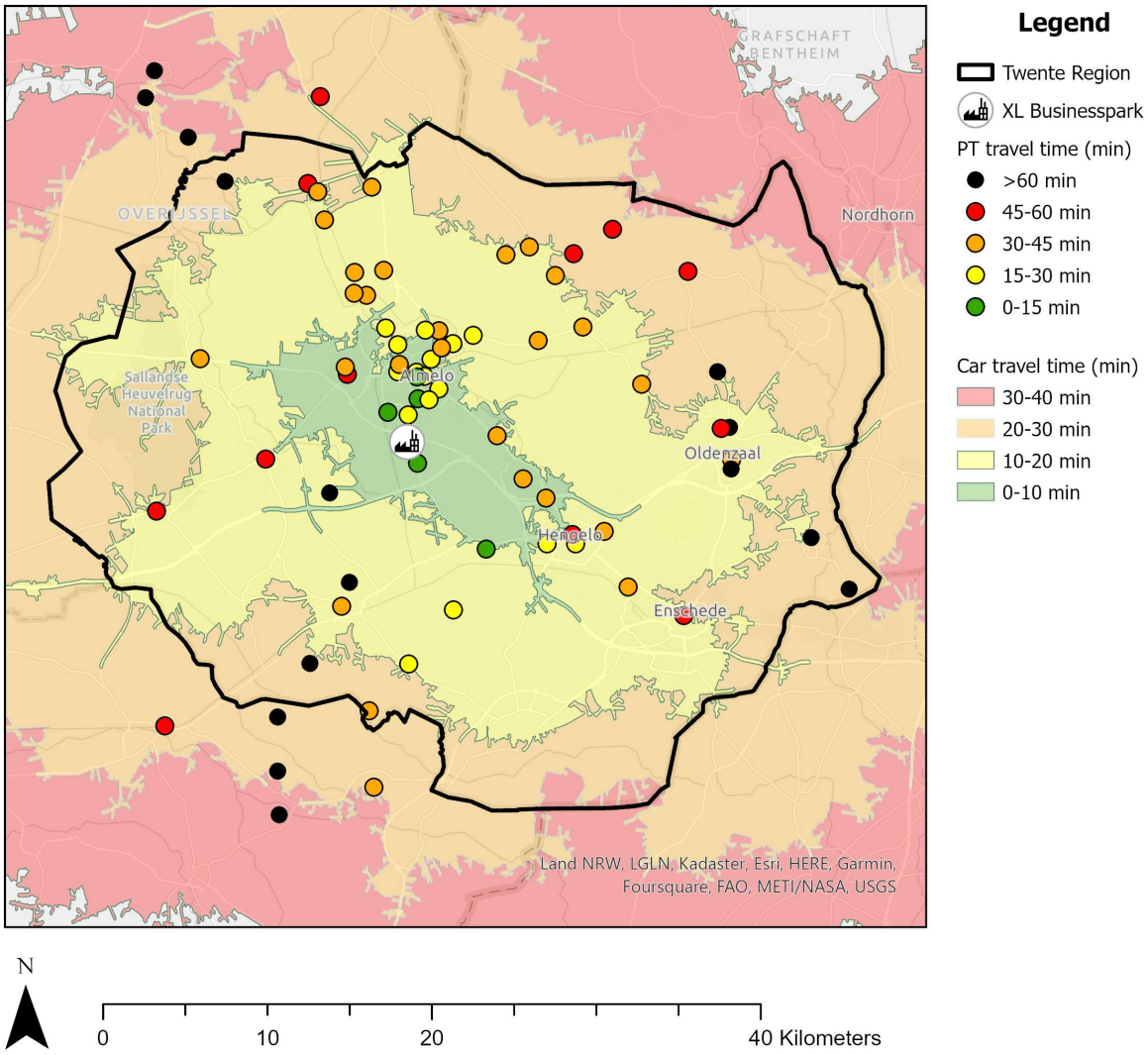

Figure 59: Depart from bus stop XL Businesspark at 15:15

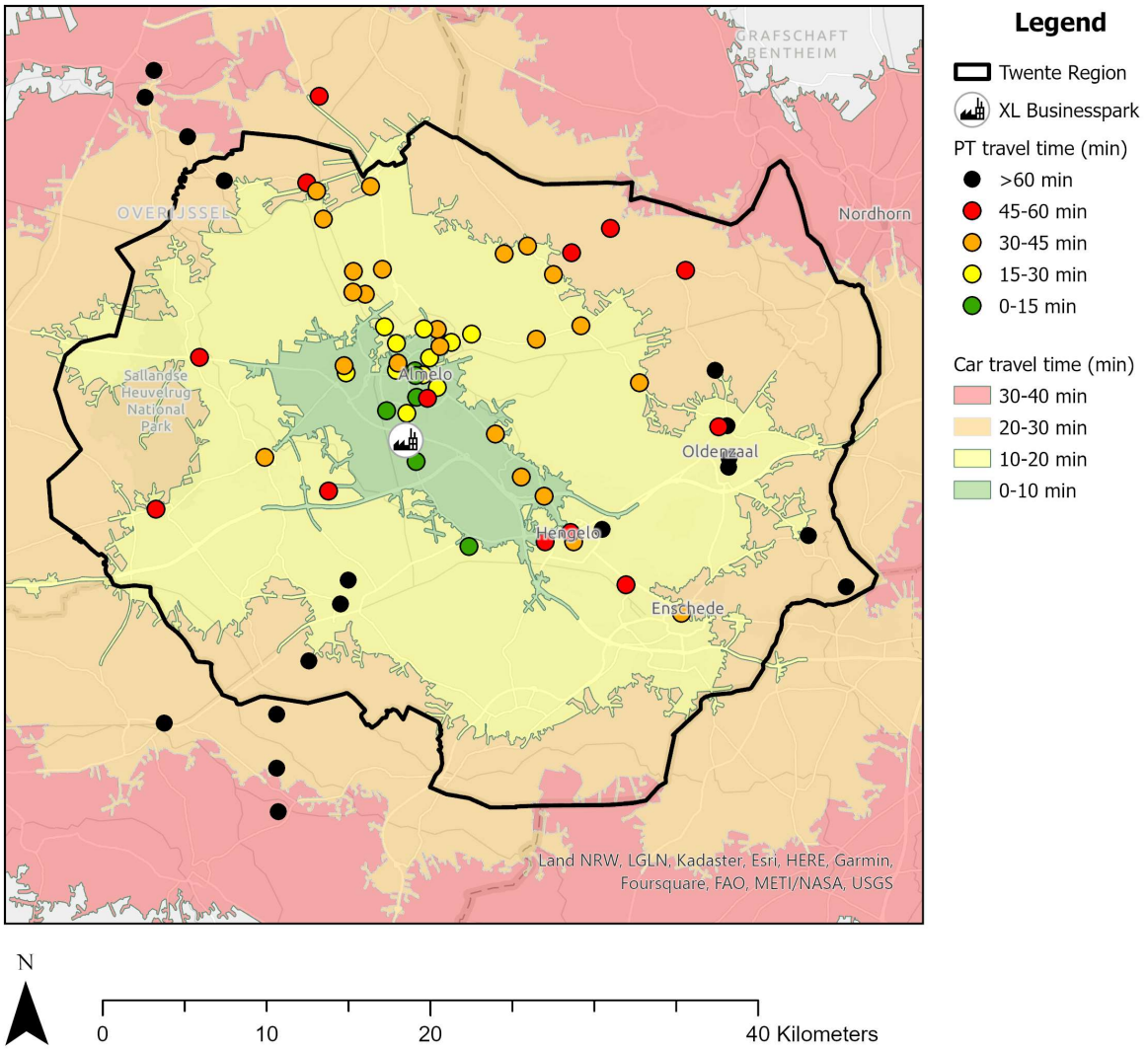

Figure 60: Depart from bus stop XL Businesspark at 15:45

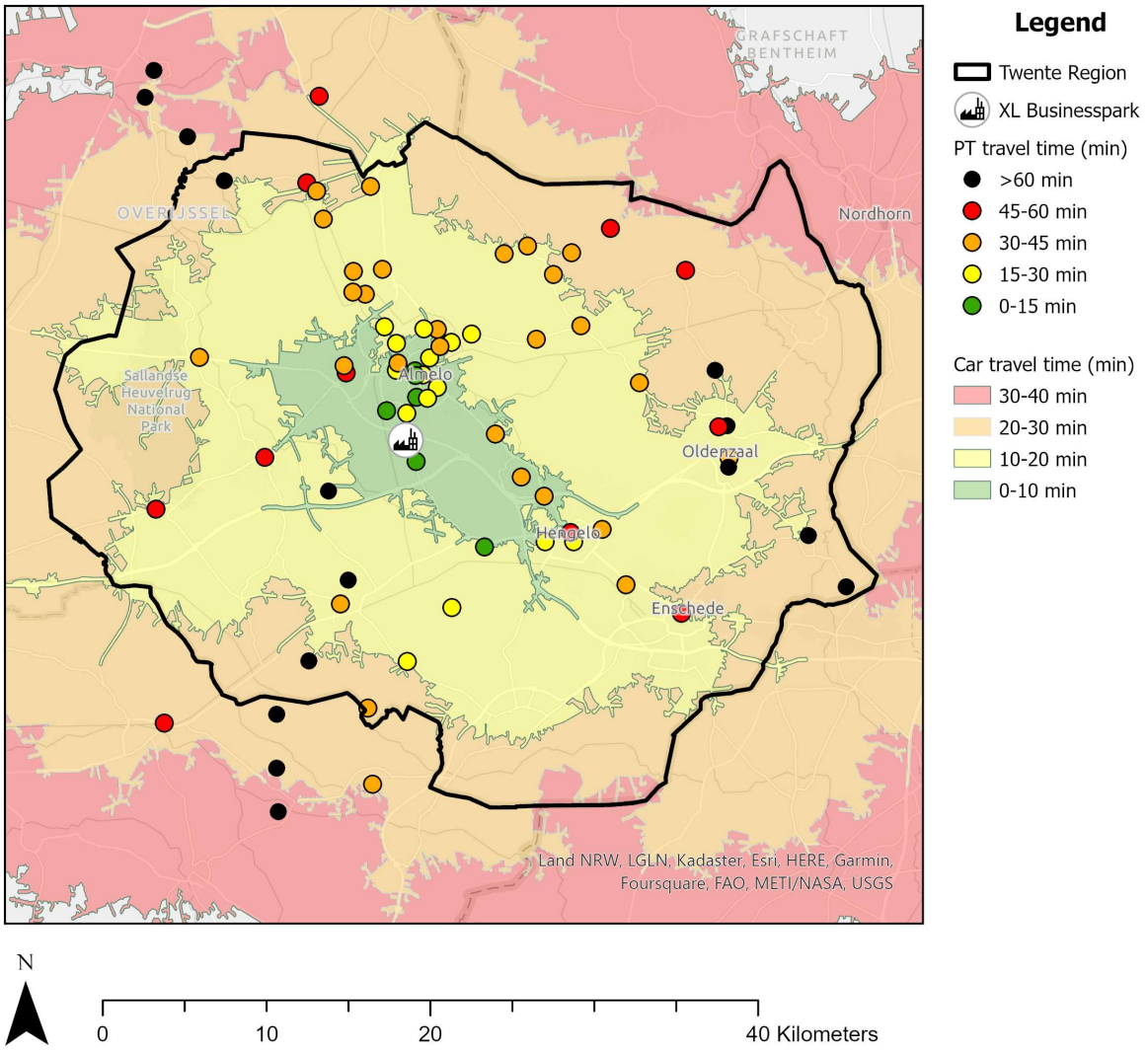

Figure 61: Depart from bus stop XL Businesspark at 16:15

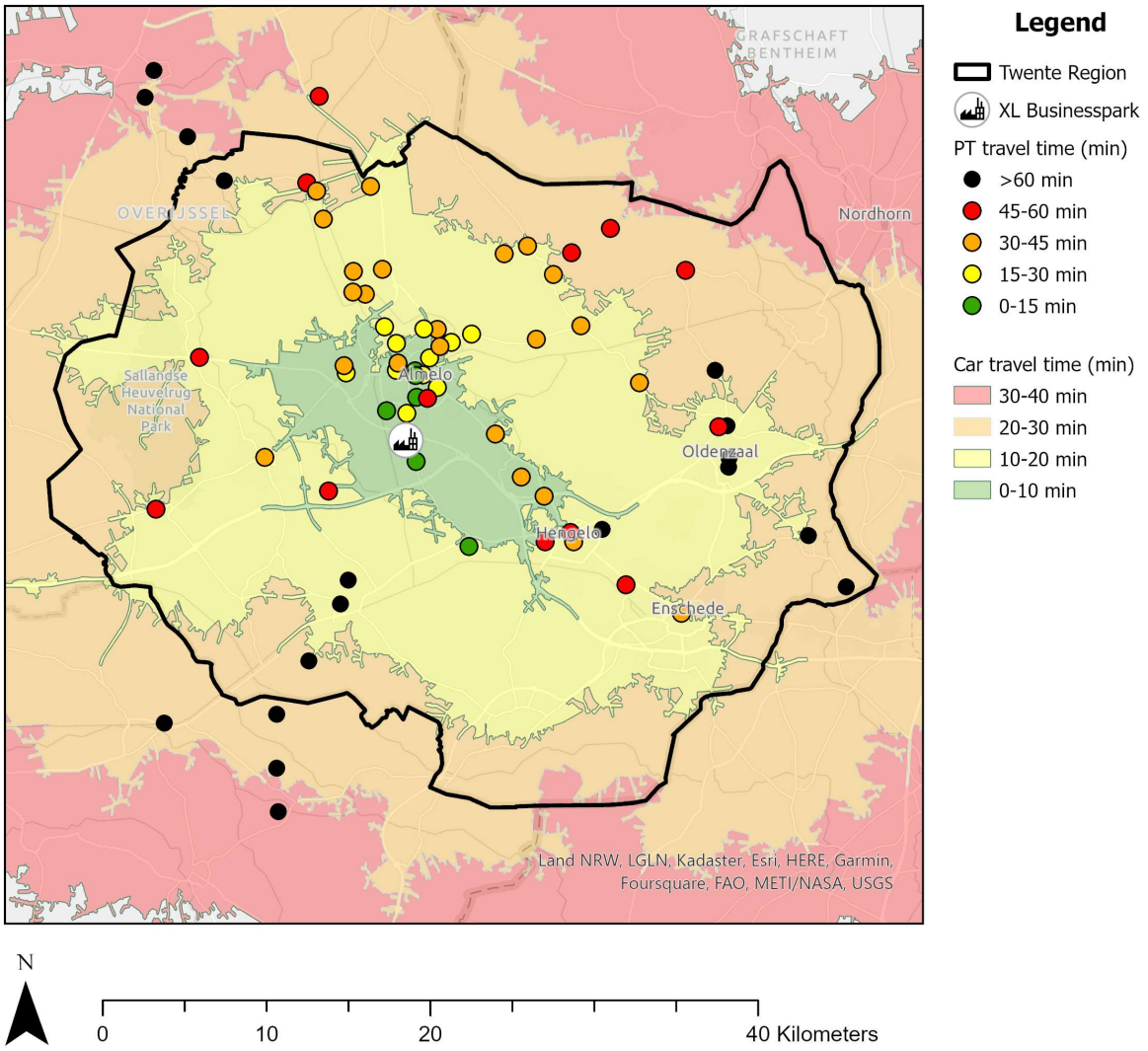

Figure 62: Depart from bus stop XL Businesspark at 16:45