FACULTY OF ENGINEERING AND ARCHITECTURE

A mobility profile-based approach to quantifying transport poverty

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Student number: 01606945

Supervisors: Prof. dr. ir. Sofie Verbrugge, Prof. dr. ir. Didier Colle
Counsellor: Timo Latruwe

Master's dissertation submitted in order to obtain the academic degree of
Master of Science in Industrial Engineering and Operations Research

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Preface

As I sat on the terrace with my grandmother watching the road ahead, every few minutes a bus passed by. A void amidst the rush hour.

Never before did I judge an empty bus as much as I did that day. It displeased me to know that a person needed to drive an empty bus in traffic, while people stand packed together in other busses. My mind started to hypothesize possible explanations for this strange phenomenon. As many do, I blamed the government that day.

When the day came to choose a master's dissertation subject, I did not hesitate to apply for this subject. I could have never anticipated then the broadness of transport poverty and the chilling implications it entails. I'm glad to have finished this research by providing aid (as little as it may be) for policymakers in combating transport poverty. But I did not finish it on my own. During this research I had help from many people, who I would like to thank.

First of all, I would like to express my gratitude towards my supervisor Prof. dr. ir. Sofie Verbrugge and Prof. dr. ir. Didier Colle, for the opportunity to conduct research in the field of transportation poverty.

Next, I would like to thank my counsellor Timo Latruwe for the many hours he spent helping me throughout this thesis. Timo Latruwe always took time to understand my work and propose new ideas. I also want to thank him for the many meetings, the practical help, and the valuable feedback during this thesis.

Finally, I want to thank my friends, who always gave me positive encouragement and support. In particular, I want to thank five person. I want to thank Evie, the person that I spent most of this pandemic with and who always helped me in moments of doubt. I want to thank Elisabeth, who with her similar subject, was always ready to listen and give me new ideas. I want to thank my brother Giel, who helped with practicalities that would take me forever to do alone. I would also like to thank my parents, for always supporting me during my thesis.

Ghent, August 2021

Sam Vandierendonck

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Sam Vandierendonck, August 2021

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by

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Abstract

Employment is paramount to preventing social exclusion as it provides the financial ability to support other aspects of life. This research elaborates on the accessibility of jobs and its importance within transport poverty. Up to this point, studies have defined job accessibility from the perspective of an individual. On top of that, these studies leave out the differentiation between jobs in order to get to the metrics of job accessibility. It is therefore still hard for policymakers to address the causes of the failures in the transportation network appropriately.

This research views job accessibility from the perspective of the company instead. The effectiveness of (existing) additions to the transportation network for commuting to the port of Ghent are measured on groups of people. The measurements are done with specifically designed metrics. This enables us to understand the patterns that emerge in this research and brings insight into good public transportation networks, company accessibility, and the needs of certain groups of people. The culmination of this research is the flowchart that can aid policy makers and managers in identifying possible improvements to the accessibility of a location.

Keywords

Transportation, Accessibility, Public transit, Jobs, Port of Ghent

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I. Introduction

Accessibility poverty within a city is a problem that has never before occurred on such a large scale as it does today. Already 50% of the world's population is estimated to live in cities, whilst it is expected that this number will only keep rising. A study by Prud'homme et al. (1999) suggests that the optimal size of a city is a function of the quality of its transportation planning. Once a city grows past this point, it becomes increasingly difficult to provide upgrades to the transportation network in order to keep the city accessible. Declining accessibility severely affects people's ability to develop and inhibits opportunities within society [1]. The New York Times headlined that transportation is "crucial to escaping poverty", backed by the research of Chetty and Hendren [2]. Only recently policymakers have grown more aware of the impact of mobility on the ability of citizens to acquire jobs, educate their children, and lead a life of social inclusion. Yet, aside from high-level quantification efforts, such as the Mobiscore and indexations by Martens, few methods exist to support policymakers in identifying the mobility interventions with the highest potential for improving quality of life in cities [3][4].

Job accessibility is undoubtedly one of the most important parts of general accessibility. In the case study of Rotterdam-The Hague of Martens et al. (2019) job accessibility is even used to describe general accessibility. Shedding light on job accessibility and on the effect of possible improvements of the transportation network are crucial if our policymakers are to address the most pressing needs first.

Up to this point, studies have defined job accessibility from the perspective of a person. This is obvious when quantifying transport poverty on an individual level. However, difficulties arise when broad meaningful indexes are defined to describe transport poverty on a metropolitan level (or even neighborhood level). The differentiation within jobs is left out in order to get to the metrics of job accessibility. Which renders it still hard for policymakers to address the causes of the failures in the transportation network appropriately.

Cities tend to have neighborhoods with more unemployment than others. These neighborhoods often have worse accessibility to the city making them excluded. Changes in the transit network should therefore also focus on these groups.

The objectives of this research are focused on job accessibility for different groups from the company perspective in the city of Ghent. The accessibility of areas with high numbers of available jobs is analysed with two intentions. Firstly, to provide insight in the effectiveness of parts of the transportation network in connecting people with their job location. Secondly, to provide insight in the effectiveness of improvements of the transportation network in connecting unemployed people with a possible job location. The patterns that emerge from the analysis of the transportation network are examined. This introduces another goal for this research: designing a flowchart set out to aid policymakers and managers in identifying how to improve the accessibility of a location.

II. Literature study

A. Transport poverty

Transport poverty is a concept embodying many different interpretations. It describes the burden and limitations that people can experience in their mobility and accessibility when performing/carrying out daily activities. As Martens states, low accessibility severely restricts the ability of citizens to acquire jobs, educate their children and lead a life of social inclusion. In other words, a person's ability to participate in the activities deemed normal in society is undermined by low accessibility [4]. Moreover, Mattioli links transport poverty to various deprivations relating to transport access and affordability [5]. Jef Allen even states that it can lead to social inequity for multiple generations as an imbalance in opportunities emerges [6]. The drivers of transport poverty include wealth, transportation price, city policies and employment. This research focuses on the latter.

B. Employment and its accessibility

Employment is paramount to preventing social exclusion as it provides the financial ability to support other aspects of life [6]. The location of a job defines other destinations as well such as

schools, shops and services. When a person without a job fails to reach new job opportunities in a reasonable amount of time due to a lack of access to public transit service in its vicinity, that person is in danger of becoming excluded [7]. This is also shown by more recent studies [8], [9].

C. Effect of the public transit service

People that live in peripheral areas with a lack of access to the public transit services are more often poor [10]. Furthermore, the classical urban land economics theories indicate that transport cost is an important determinant of land value [11]. The land value increases as a result of the decreasing transport cost and therefore increasing the costs of housing in city centers. Lower-income residents are thus pushed to more affordable, but also more expensive areas to access [12]. Poor people thus encounter more limitations in access to jobs, education and social networks, or in other words to their 'right to the city' [13]. In this manner they end up in a 'poverty trap', because of the increased transportation costs. On the other hand, the presence of good public transit service is indicated to encourage a shift away from private vehicles and therefore results in less congestion and pollution within the city [14].

D. Indexations of transport poverty

Different studies present possible ways to index transport poverty. For instance, the Flemish government developed the Mobiscore [3]. This is a score given to a property indicating how sustainable its location is in terms of accessibility to public transport, shops and businesses, schools and other essential facilities. Supported by objective and complete information, this score wants to raise awareness about the impact on mobility and environment caused by the location of a residence. Furthermore, Martens is an important researcher who invented some prominent indexation such as the accessibility poverty index (API), the potential mobility index (PMI) and the disadvantage impedance index (DIX) [4][15].

E. Measurements of job accessibility

In terms of measuring job accessibility a couple of studies are relevant. Firstly, the Brookings Institute (2011) provides a study of the connection between public transportation and job accessibility in major US cities [16]. Brookings relies primarily on a metropolitan level analysis of job access. One metric of job access used by Brookings is the share of jobs accessible to an average resident within a region. No differentiation is made between neighborhoods, which masks inequalities within a city since outliers are not visible in an average. Some people have very high levels of job access while others are isolated.

Secondly, Kaufman et al. (2015) of the NYU Rudin Center for Transportation (NYU RCT) created a ranking of neighborhoods of the New York City region based on their corresponding accessibility to jobs with use of the public transportation network [17]. By focusing on the neighborhood level, the NYU RCT has identified communities that are substantially underserved by the public transportation system. The accessibility to jobs is measured according to the amount of jobs accessible within 60 minutes from the neighborhood. They state that variations in levels of transit affect unemployment rates of neighborhoods, travel modes and incomes.

III. Methodology

A. Work method

To conduct the analysis for this study, Conveyal was used. This is a powerful analysis tool specifically designed to understand the accessibility of locations with multi-modal transportation networks. Different research-backed accessibility metrics can be determined with the help of this tool. Different scenarios are created to examine the effect caused by changes in the transportation network in the region of Ghent.

A.1 Metrics

The effects are analysed visually and with three metrics from the perspective of a company. Opportunity data sets are needed to measure the metrics. These data sets can be a list of coordinates each corresponding to a number representing the amount of jobs, supermarkets or anything else that can be found at those coordinates. This is needed to calculate the amount of opportunities that are accessible within a certain time (and setting) for any location within the analysed region. The opportunity data set can also be a shapefile. A shapefile contains coordinates of outlined areas on a map instead of single point coordinates.

The first metric is the measurement of the regional effect of certain modifications. It is represented by the difference in the number of people (of a certain group) that can reach the company within a certain time. Note that although this metric is easy to understand, it is heavily dependent on the set maximal travel time (and therefore fluctuations). If the whole opportunity data set is accessible within the set travel time for both scenarios, the difference in the number of people that can reach the location within a certain time is zero. The effect of the modifications may only be visible with this metric with a lower (or higher) maximal travel time.

The second metric is the average transportation time reduction by the introduction of the modification. This is measured by calculating travel time differences of areas across the region where a lot of people of a certain group reside. The analysed groups are employees and unemployed job seekers.

The third metric is the average number of transfers per person. Transfers in a perfect transportation network do not pose a problem but a realistic network has traffic that can cause delays in arrival time. This can lead arriving to late at a stop and missing the transfer of transit mode. In general, the accessibility via transit is affected in reality by transfers. Limiting the number of transfers should therefore be a secondary goal of policy makers.

The parameters that are needed for the analysis of the accessibility metrics are the travel time cutoff, the travel time percentile, the access mode, the choice of transit modes and the maximal amount of transfers.

B. Exploration of open-source data

To conduct this research open-source data was explored. Important data to simulate the transportation network include the geographical street map data (imported by OpenStreetMap or OSM), the public transit data of the region (imported as General

Transit Feed Specification or GTFS data) and possible destination nodes. Gathering data of the possible destination nodes, except job locations, happens with overpass-turbo.

B.1 Travel motives

In order to analyse the travel motives of people, the most important data-sets are the IDB-tables (short for Investigation of Displacement Behavior) [18]. The largest differences between statuses (such as unemployed, student, retired person, ...) of people are found in motives such as work, education and bringing or picking up someone or something. Motives like shopping and recreation (and by extension services) are of equal importance for the various statuses. When looking solely at motivation of displacement, shopping is the most important consisting of 25% of all displacements of the average person in Belgium. Working is only on the fifth place with 12%. This is due to the travel motive of working only being relevant for the working population which makes up around 40% of the total population in Belgium [19]. On the other hand, shopping is relevant for the whole population. When only looking at the travel motives of the working population, work is the most important travel motive, followed by shopping. When limiting the travel motive of shopping to supermarkets (most relevant in tackling transport poverty), people residing in Ghent all have good accessibility to this type of location. This implicates that difficulties in the transportation network will become more clear when analysing job accessibility alone.

B.2 Commuting data

Commuting behavior to Ghent is attainable with the data from Census [20]. This data contains the commuting from and to every statistical sector in Belgium. A statistical sector is the smallest territorial unit used in Belgium for the dissemination of statistics at a more detailed level than the municipal level [21]. The data from Census is described in short as the commuting data and helps to understand commuting patterns. The total amount of people employed in Ghent is estimated at 141.572. 45,25% (or 61.228) of those are residential in Ghent and 49,94% (or 70.707) live elsewhere in East Flanders (the province of which Ghent is the capital). Meaning most people with a job in Ghent come from within the analysed region.

If the commuting data is summed over all job locations, a new data set is formed containing the amount of people that work in each statistical sector. This can be used to find the statistical sectors in Ghent with the most job opportunities, called the employment attraction poles. There are four statistical sectors that emerge as employment attraction poles; two in the port of Ghent, one in the city center and one south of the city center. This last one is the statistical sector that encompasses the academic hospital of Ghent (UZ Gent). The two employment attraction poles in the port of Ghent are Texaco and Rostijne, which encompass the corporations Volvo Cars and ArcelorMittal respectively. These companies have the largest number of employees in the port of Ghent [22]. However, most of the transit routes pass through the city center, whilst only a few transit routes pass by the port of Ghent, partly forming the idea behind to inspect the transport accessibility of this area.

To simplify the research, the accessibility of the port of Ghent is measured for two specific locations; the entrance of Volvo Cars and ArcelorMittal. For both of these statistical sectors separately, the commuting data is used to visualise the statistical sectors where their respective employees live. This can then be used to pin-point the locations with a high number of employees in their vicinity, called aggregation points. These aggregation points are needed for the metric of travel time reduction and visualised in figures 1 and 2 for employees of Texaco and Rostijne respectively. The shapefile of the statistical sectors of Ghent can be extended with two columns containing the number of employees of Texaco and of Rostijne that are residential in the corresponding statistical sector.

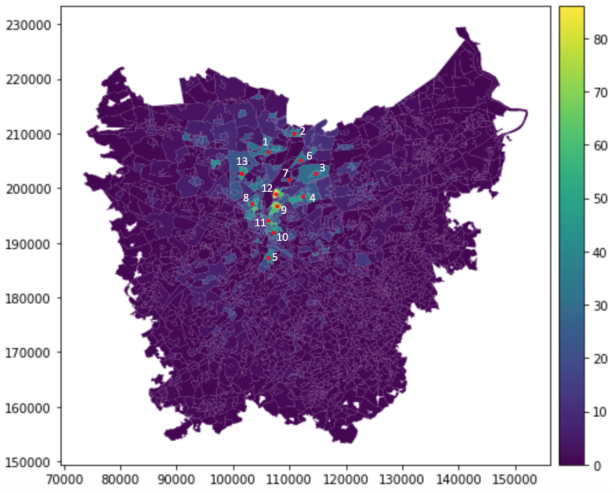

Fig. 1: Aggregation points for employees of Texaco

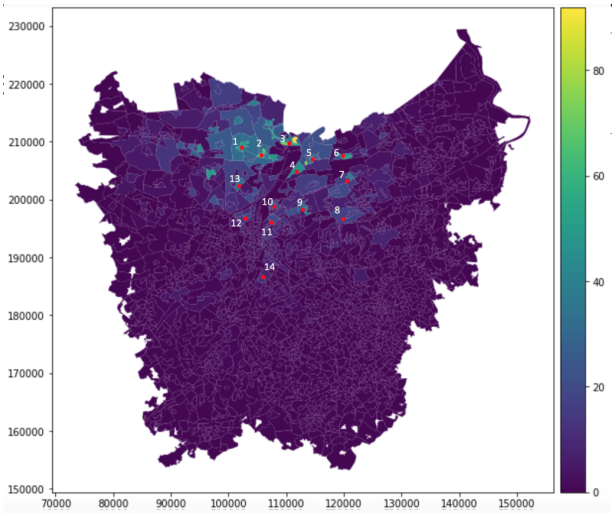

Fig. 2: Aggregation points for employees of Rostijne

B.3 Unemployment data

The companies in the port of Ghent currently battle difficulties in filling in all job openings [23]. Therefore, the unemployed jobseekers form an important group to analyse. The data of this group is available per statistical sector in Ghent and can

therefore also be used to make aggregation points with high unemployment (rates). This is visualised in figure 3. The underlying map here represents the accessibility of other facilities important for unemployed people. The shapefile of the statistical sectors of Ghent is extended with a column containing the number of unemployed people that are residential in the corresponding statistical sector.

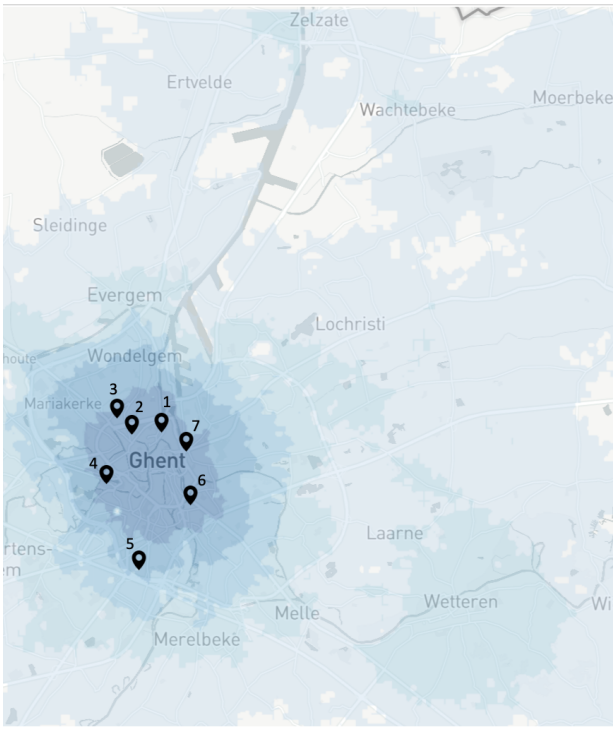

Fig. 3: Aggregation points of unemployment in Ghent

IV. Effects of existing additions to the public transportation network for the Port of Ghent

The additions that are analysed for the employees include the five private bus routes of Volvo Cars and ArcelorMittal, the bus routes of Max Mobiel for the port of Ghent and the ferry. Since currently a project is in progress to develop a new railroad line that would better connect the port of Ghent with the city center, the effectiveness of this extra railway line is measured as well. The results of the metrics are shown in table I. Metric 1 is the percentage increase in extra employees that can reach the site within 60 minutes caused by the addition. Metric 2 is the average travel time reduction caused by the addition. Metric 3 is the percentage increase (if a negative number) or reduction (if a positive number) in the average number of transfers needed to get to the site within 60 minutes caused by the addition. Although it is opted to reduce the number of transfers, a percentage increase in number of transfers is not necessarily bad. If the other metrics are positive, then this increase is only due to more people being able to reach the site within 60 minutes. Metric 3 is thus only relevant if it is a positive number. Voc and ArM represents the effect measured for the employees of Volvo Cars and ArcelorMittal, respectively.

TABLE I: Measured metrics of each addition for employees

Addition	Metric 1		Metric 2		Metric 3	
	VoC	ArM	VoC	ArM	VoC	ArM
Ferry	11.80	-	6.27	-	-53.28	-
Max Mobiel	2.19	1.35	2.21	-	-11.28	-
Private bus	12.28	54.14	2.93	33.67	6.93	24.83
New train	6.21	2.64	4.95	3.19	27.61	-

V. Improvements to the public transportation network to provide growth in workforce in the Port of Ghent

The improvements that are analysed for the unemployed people include the new railway line and a changed bus route. The results of the metrics are shown in table II. The metrics are the same as described in section IV except for the travel time cutoff of 60 minutes, which becomes here 45 minutes. Voc and ArM again represents the effect measured for the employees of Volvo Cars and ArcelorMittal, respectively.

TABLE II: Measured metrics of each improvement for unemployed people

Addition	Metric 1		Metric 2		Metric 3	
	VoC	ArM	VoC	ArM	VoC	ArM
New train	28.65	77.07	10.63	6.52	-21.32	-
Changed bus	4.32	-	3.80	1.63	-17.51	-

VI. Results and discussion

Combining the results, the patterns that emerge when examining all (possible) additions to the transportation network and their effect on the targeted districts are clarified. This is done in order to better comprehend the components of a good public transit network, the accessibility of a company and the needs that certain groups of people require from the transit network for commuting.

A. Additions to the transit network

A.1 Ferry

The ferry connects Volvo Cars at the east side of the canal to the west side of the canal. The ferry's importance lies in the absence of a bridge close to its location. And just as bridges form important connections in the transportation network, so does this ferry. It effectively enables employees to reach the work place faster. Its benefits also extend to employees that go by car to the site since the ferry is able to transport cars as well. The ferry's importance is not limited by its effect solely on commuting to Volvo Cars, but other transportation motives may also be positively influenced by the ferry. These motives are not further investigated in this research. The benefits of the ferry on commuting are not felt by the employees of ArcelorMittal, since this site lies close to the bridge of Zelzate and the bridge of the E34 highway across the canal.

Ideally, the ferry is replaced by a bridge to secure a permanent connection between the two banks of the canal. A bridge has a

two main advantages that follow from extensively examining the transportation network of Ghent.

Firstly, a bridge enables the use of a bus route that can form a direct (and faster) connection with the port of Ghent via the west side by eliminating one transfer. A bus would make this route also a better option for people using the public transit that work for other companies located in the port of Ghent than Volvo Cars. Moreover, the route with the ferry requires a lot of walking since its stop is located almost 1 kilometer from the next bus stop.

Secondly, the bridge would also improve the transportation time for a person residential at the west side of the canal that commutes by car to the port of Ghent. The improved transportation time by car would extend to the whole western part of Ghent. This makes the alternative route that exists right now passing through Dampoort and its often congested roundabout less attractive.

A.2 Max Mobiel

Max Mobiel is an independent company that offers commuting employees an alternative to the existing public transit. Volvo Cars and ArcelorMittal employ Max Mobiel to facilitate commuting since both sites can sometimes be difficult to reach by public transportation alone at some of the hours that the employee's shifts begin. Max Mobiel provides their service only when employees need it (or in other words when the public transit is not available), which means their benefit to the transportation network comes from their flexibility in working hours. The measurements provide no insight in flexibility since the hour of departure is not taken as a parameter. The only significant difference is found in metric 3 for employees of Volvo Cars, since the percentage of employees that do not need to transfer in order to get to the site drops with the inclusion of Max Mobiel. This comes from the fact that the travel time reduces for people if they transfer to Max Mobiel in Dampoort instead of staying on the same bus.

A.3 Private busses

The private busses are designed to make the company's site more easily accessible for people that are not able or prefer not to use a car. These locations are found further away from the site; not in cities and not on main connection roads to the site. A significant difference in effectiveness is found between the private busses of ArcelorMittal and Volvo Cars. Two important parameters are found to declare the effectiveness of the private busses deployed by a company.

The first parameter is the accessibility of the site by public transit. The closer a company is located to the center of a city, the better it is(or should be) accessible with public transit and the less benefit there is from introducing a new (private) bus route. The positioning of the site in the public transit network can therefore give a company an initial idea in the need for private busses.

The second parameter is the residential location of the company's employees. If the employees reside outside the city, some will have public transit available that connects them to the closest city. The closest city may not be close to the site of the company. Providing a private bus route that forms a direct connection for commuting to the site from the residential location of the company's employees can therefore be very effective. If, however, the employees reside in and around the center of the city, most will have decent public transit available. The company should therefore focus the private busses on providing fast connections between the city and their site. This should not be limited to one connection from the closest accessible point at the edge of the city but should extend to multiple connections from accessible points all around the edge of the city.

A.4 New railway line

The new railway line in development will provide a fast and stable connection between the port of Ghent and Dampoort, whilst Dampoort provides access to the different parts of Ghent. On top of that even better connections between the train stations across East Flanders to the port of Ghent will exist, making transfers less likely to be needed. Trains have other benefits in comparison to busses including the transportation of more passengers and not being hindered by traffic. The project is estimated to cost 30 million euros, but of which deems worthy since its effects will extend to transportation of goods and other transportation motives of people besides commuting.

A.5 Changed bus route

The changed bus route improves the transportation time of people living in the vicinity of the stops. This would become even more effective when the new train is part of the public transit network. It shows first hand how difficult changes in the public transit network inside a city are. Most improvements will come from changes of the road network itself. Tolhuis and Wondelgemstraat are located only 1.4 and 2.3 kilometers from the site of Volvo Cars but still have transportation times around 40 minutes at best. This illustrates that some problems cannot be solved completely without structural changes of the transportation network.

B. Districts accessibility: Nieuw-Gent

Nieuw-Gent is the only statistical sector with a high unemployment rate that is unaffected by any changes in the public transit network. Two public transit routes pass through there and provide a connection with the largest train station of Ghent, Gent-Sint-Pieters, and Gent Zuid, two of three public transit hubs of Ghent (the third one being Dampoort). But it is located in the most southern part of Ghent and will therefore always experience longer travel times to reach the port in the north. The only possibility for better accessibility to the port could be via a direct connection to Dampoort or immediately to the port.

C. Public transportation planning

Lastly, a flowchart is set out to aid policymakers and managers in identifying how to improve the accessibility of a location, as is shown in figure 4. In order to better understand this flowchart and the reasoning behind it, an explanation follows in this section. If employees residing at a certain location have difficulties to access the site of the company by transit, first the mobility should be calculated from that location to the site. The

mobility can be measured as the quotient of the aerial distance and the travel time by car.
If the mobility is low, then the road network causes the low accessibility in the first place. Which implicates that changes are needed in the road network or commitment to alternative travel options (such as train or bike) to improve accessibility.
If the mobility is high, the transit network causes the low accessibility. In this case, subsequent checks are needed in order to determine the needed improvement. Firstly, the availability of transit at the location is checked. Public transit always flows through important transit hubs. Transit hubs each have a high number of different bus routes stops at its location. Ghent contains three so called transit hubs: Gent-Sint-Pieters, Gent Zuid and Dampoort. If the employees' residential location has no connection with a transit hub, then making one should be prioritised. This should be done for general accessibility and not only for job accessibility. Secondly, transit should provide a connection to the site of the company (the amount of transfers is not yet important). If this is not the case, a connection should be made between the transit hub (that is accessible) and the site. Thirdly, transit should provide a direct connection to the site. Direct connection can mean one of two things: a connection without the need of transfer or stricter, a connection without passing a transit hub first. This should be installed if not the case. If however, all of these things exist in the transit network, the speed of all connection should be questioned.

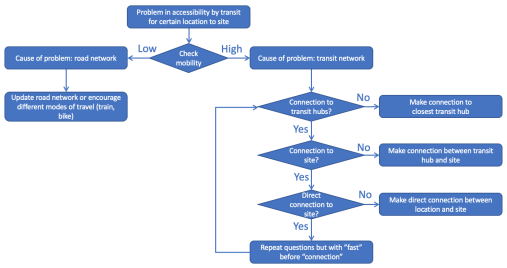

Fig. 4: Flowchart to find improvement

VII. Conclusion

Up to this point, studies defined job accessibility from the perspective of a person. On top of that, in order to get to the metrics job accessibility, the differentiation between jobs was left out. This yields it still hard for policymakers to address the causes of the failures in the transportation network appropriately. The objectives of this research focused on job accessibility for different groups from the perspective of the company. Different research-backed accessibility metrics are determined to examine the accessibility of the areas with a high number of available jobs with public transit in order to provide more insight into the failures of the transportation network for commuting. Different scenarios are created to examine the effect caused by changes in the transportation network. The analysed region in this research is Ghent. In Ghent, there are four statistical sectors that emerge as employment attraction poles: two in the port of Ghent, one in the city center and one south of the city center. The latter is the statistical sector that encompasses the academic hospital of Ghent (UZ Gent). The two employment attraction poles in the port of Ghent are Texaco and Rostijne, which encompass the corporations Volvo Cars and ArcelorMittal, respectively. These companies have the largest number of employees in the port of Ghent, but have few bus routes passing there. Companies even deploy private busses to improve accessibility. Therefore this research analyses the effect of the additions of the transportation network for the employees in the port of Ghent. The focus is extended to unemployed job seekers, since these companies are currently battling difficulties in filling in all job openings. Patterns emerged from the analysis of this research and the insight it brought into good public transportation networks, company accessibility, and the needs of certain groups of people is elaborated. The culmination of this research is a flowchart that can aid policy makers and managers in identifying possible improvements in accessibility of a location.

This research gives an in-depth analysis of commuting to the port of Ghent and can form a guide for improvements in this area. The simulations of this research are imposed to some limitations. It does not include traffic and traffic jams or the timing of the trip. The commuting data is also somewhat outdated since it dates back to 2011 and does not contain information about every person exactly. t is important to note that the flowchart is very broad and therefore offers no assurance of applicability in every situation. Instead it forms more of a basis for guidelines than an actual guideline.

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Abbreviations

API	Accessibility Poverty Index
PMI	Potential Mobility Index
DIX	Disadvantage impedance index
GTFS	General Transit Feed Specification
OSM	OpenStreetMap
IDB	Investigation of Displacement Behavior

Chapter 1

Introduction

Accessibility poverty within a city is a problem that has never before occurred on today's scale. It is expected that in the near future more people will live in cities, while today already 50% of the world population lives in cities. A study by Prud'homme et al. (1999) suggests that the optimal size of a city is a function of the quality of its transportation planning. Once a city grows past this point, it becomes increasingly difficult to provide upgrades to the transportation network in order to keep the city accessible. Declining accessibility severely affects people's ability to develop and inhibits opportunity within society [1]. The New York Times headlined that transportation is "crucial to escaping poverty", backed by the research of Chetty and Hendren [2]. Only recently policymakers have grown more aware of the impact of mobility on the ability of citizens to acquire jobs, educate their children, and lead a life of social inclusion. Yet, aside from high-level quantification efforts, such as the Mobiscore, and by Martens, few methods exist to support policymakers in identifying the mobility interventions with the highest potential for improving quality of life in cities [3][4]. Job accessibility is undoubtedly one of the most important parts of general accessibility. In the case study of Rotterdam-The Hague of Martens et al. (2019) job accessibility is even used to describe general accessibility. Shedding light on job accessibility and on the effect of possible improvements of the transportation network are crucial if our policymakers are to address the most pressing needs first.

1.1 Problem statement

Up to this point, the relevant studies define job accessibility from the perspective of a person. This is obvious when quantifying transport poverty since that is important on an individual

level. But the difficulties arise when broad meaningful indexes are defined to describe transport poverty on a metropolitan level (or even neighborhood level). The differentiation within jobs is left out in order to get to the metrics of job accessibility.

The indexes try to provide the ability to rank cities by giving scores to a city. But providing insight into the effect of parts of the transportation network or of possible improvements is often not examined. This makes it still hard for policymakers to address the causes of the failures in the transportation network in the right way. Therefore this research analysis job accessibility from the perspective of the companies.

Cities tend to have neighborhoods with more unemployment as is the case for Ghent and also stated by the study of Kaufman et al. (2015) to be the case in New York city. These neighborhoods often have worse accessibility to the city and as a result are isolated. Changes in the transit network should therefore be focused to this group. The lack of insight into the effect of changes limits the ability of policymakers to address this problem.

1.2 Goal

The objectives of this research are focused on job accessibility for different groups. Job accessibility is examined from the perspective of the company. The accessibility of the areas with a high number of available jobs is analysed with two intentions.
Firstly, to provide insight into the effectiveness of parts of the transportation network in connecting people with their job location using simulations.
Secondly, to provide insight into the effectiveness of improvements of the transportation network in connecting unemployed people with a possible job location using simulations.

The patterns that emerge from this analysis of the transportation network are examined. This introduces another goal for this research: designing a flowchart set out to aid policymakers and managers in identifying how to improve the accessibility of a location.

1.3 Outline

Chapter 2 elaborates the literature concerning the topics of this research. First, transport poverty and its relevance in the current society are explained. Then, the most prominent indexes that are established to describe transport poverty are reviewed. This is followed by an overview of the important researches about job accessibility. Lastly, the research questions of this study are formulated.

Chapter 3 provides the methodology to answer the research questions. Firstly the used program Coneyal is explained together with the general description of the used metrics. This is followed by presenting the used data sources and the preparation of this data in order to be able to get the results.

Chapter 4 applies the metrics of accessibility to the port of Ghent. The effectiveness of existing additions to the transportation network for the workforce are measured.
Chapter 5 examines the possibilities and their impact to extend the public transportation network in order to provide growth in workforce in the port of Ghent.

Chapter 6 brings the answers to the research questions inside an interesting discussion and ends with the general conclusion of this research.

Chapter 2

Literature study

Since the scope of this research is set at job accessibility, the literature concerning transport poverty and its relationship with job accessibility is examined first. Then the prominent researches solely about job accessibility are examined. This is followed by a summation of the important parts of literature that help form this study's approach and scope. Lastly, the research questions are formulated.

2.1 Transport poverty

Transport poverty is a concept embodying many different interpretation. It describes the burden and limitations that people can experience in their mobility and accessibility for and of daily activities. As Martens states, a situation of low accessibility severely restricts the ability of citizens to acquire jobs, educate their children and lead a life of social inclusion. In other words, a person's ability to participate in the activities deemed normal in his/her society [4]. Mattioli links transport poverty to various deprivations relating to transport access and affordability [5]. Jef Allen even states that it can lead to social inequity for multiple generations as an imbalance emerges in opportunities [6]. This research and most researches that were found, try quantifying accessibility poverty aspect of transport poverty. Other aspects are mobility poverty [4] and transport affordability [7]. The drivers of transport poverty include wealth, price of transportation, city policies and employment and this research will focus on the latter.

2.1.1 Employment and its accessibility

Employment is paramount to preventing social exclusion as it provides the financial ability to support other aspects of life [6]. The location of the job defines other destinations as well such as schools, shops and so on. When a person without a job fails to reach new job opportunities in a reasonable amount of time due to a lack of access to public transit service in its vicinity, that person is in danger of becoming excluded [8]. This is also shown by more recent studies [9], [10].

2.1.2 Effect of the public transit service

The people that live in peripheral areas with a lack of access to the public transit service are more often poor [7]. The classical urban land economics theories indicate that transport cost is an important determinant of land value [11]. The land value increases as a result of the decreasing transport cost and therefore increasing the costs of housing in city centers. Lower-income residents are thus pushed to more affordable, but also more expensive areas to access [12].
Poor people encounter more limitations in access to jobs, education, social networks or in other words their 'right to the city' and they end up in a 'poverty trap' because of the increased transportation costs [13].
On the other hand, the presence of good public transit service is also indicated to encourage a shift away from private vehicles and therefore less congestion and pollution within the city [14].

2.2 Indexations of transport poverty

This section reviews important researches that provide indexes or quantification methods for transport poverty. Additional focus is made on how each index covers job accessibility.

2.2.1 Mobiscore

The Mobiscore is a score given to a property indicating how sustainable its location is in terms of accessibility to public transport, shops and businesses, schools and other essential facilities [3]. This is developed by the Department of Environment of the Flemish government. Supported by objective and complete information, this score wants to raise awareness about the impact on

mobility and environment caused by the location of residence. This can then encourage people to live closer to facilities and therefore contributes to core strengthening, with numerous positive consequences. In the long run, this leads to less fragmentation, less pollution and nuisance, higher biodiversity and fewer vehicle miles. The last one is a real problem in Flanders which partly causes the ecological foot print of the citizens to be higher than those of neighbouring countries [15]. It is part of the broader commitment of engaging citizens in environmentally responsible behavior and consumption.

The Mobiscore uses the IDB-tables (short for Investigation of Displacement Behavior) as basis to determine the relevance of each type of facility. These tables are part of an ongoing research by the Department of Mobility and Public Works of the Flemish government into the transportation behavior of its citizens. The IDB is done with a survey of at least 8,000 individuals, spread over five consecutive survey years containing at least 1,600 individual surveys. This is an important study that will be used within this research as well.

The basic formula for calculating the Mobiscore is determined by calculating the environmental impact of the trips that are expected to be made on average by a resident at that location:

$$Mobiscore \sim \sum_{i=1}^{n}(Frequency_i \cdot Distance_i \cdot \sum_{j=1}^{m}(\%Modus_{ij} \cdot Environmental\ cost_j)) \qquad (2.1)$$

Whereas the frequency is the frequency of travel of a given motive i, the distance is the average distance traveled per trip for a particular motive i, the modus is the probability that a particular mode j is used for a particular motive i and the environmental cost is the cost per distance for a given mode of transport j.

The accessibility of jobs is reduced to the average distance covered to reach this destination. Although there are differences in this distance per municipality, this more accurate data is said to not be applicable for the Mobiscore. Due to the relative heavy weight given to the accessibility of jobs, the Mobiscore would have discontinuous values for neighboring municipalities. This is undesirable for this metric since the distance to the job develops in a continuous manner just as for other facilities.

2.2.2 Accessibility poverty index

The accessibility poverty index is established by Martens et al. [4]. A different approach to the quantification of accessibility (in this case) poverty is working with a minimum threshold of accessibility. The index is measured using three components: the accessibility poverty line (or threshold), the share of the population below the poverty line and the exact level of accessibility experienced by persons below the poverty line. Figure 2.1 illustrates these three components. The more people below the accessibility poverty line and the lower the level of accessibility experienced by people below the accessibility poverty line, the less fair a transport system is. The accessibility poverty index (or API) thus represents the fairness of the transport system or forms an equity assessment. This index has two main advantages. First, it provides a single number making it easy comparable for different regions. Second, it is applicable for different groups of people making it divisible for more accurate estimations of fairness. Different groups could have different thresholds. One remark for the usage of this index is that it should only be used to measure accessibility of relevant locations for each group of people. For example, a household without children has no need for accessible schools.

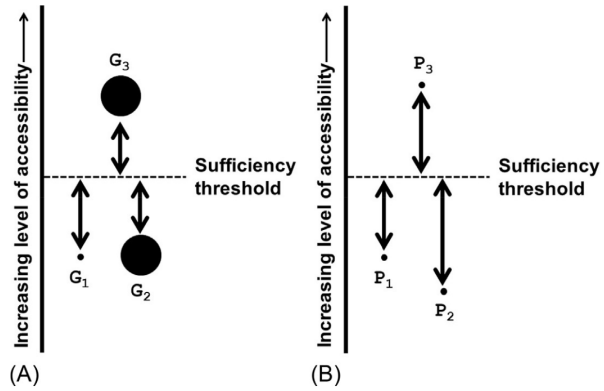


Figure 2.1: Visual representation of (A) the prevalence of accessibility shortfalls and (B) the intensity of accessibility shortfalls

In the case study of Rotterdam-The Hague in the same paper, job accessibility is not only examined for the importance of employment, but also because an analysis of job accessibility provides insight into the general accessibility of a person residing on a certain location. The reason is that jobs tend to be distributed over an urban area and therefore give an indication of accessibility.

2.2.3 Potential mobility index

Martens et al. (2019) provide an index to measure mobility as well. The potential mobility index (or PMI) is based on the quotient of the aerial distance and the travel time on the transport network between origin and destination. This quotient thus represents the aerial speed of getting to the location. This is measured for all facilities needed for different groups of people from a residence. The combination of these measurements is then called the PMI. The PMI is necessary because the level of accessibility (measured to the threshold) alone can not give insight into structural failures of the transportation network. The PMI analyzes the contribution of the transportion network to accessibility. Just as for the API, the PMI has to be measured at an individual or group level.

The combination of the PMI and API allows to determine whether the transportation network or the lack of close destinations is the reason for a person's poor accessibility to facilities.

2.2.4 Disadvantage impedance index

The disadvantage impedance index (DIX) provides a possibility to review differences between policy alternatives in order to limit transportation poverty. This is done by using measures of accessibility in a simulation environment, with trip-making behavior, and survey data [16]. This approach is copied in this research.

The results of the index indicate that even a slight improvement in accessibility and travel quality can make a significant difference in lowering transport disadvantages.

2.3 Measurements of job accessibility

The Brookings Institute (2011) provides a study of the connection between public transportation and job accessibility in major US cities [17]. Brookings relies primarily on metropolitan level analysis of job access. One metric of job access used by Brookings is the share of jobs accessible to an average resident within a region. No differentiation is made between neighborhoods and therefore masks inequalities within a city since some people have very high levels of job access while others are isolated, just as indexes can do.

Kaufman et al. (2015) made a ranking of neighborhoods of the New York City region based on their corresponding accessibility to jobs with use of the public transportation network [18]. By focusing on the neighborhood level, the NYU Rudin Center for Transportation has identified communities that are substantially underserved by the public transportation system. The accessibility to jobs is measured according to the amount of jobs accessible within 60 minutes from the neighborhood. They state that variations in levels of transit affect unemployment rates of neighborhoods, travel modes and incomes. The highest incomes are found in neighborhoods with the most access to jobs via transit, the lowest incomes are situated in areas with moderate transit access, and average incomes are prevalent in neighborhoods with the least access via transit. Accessibility to jobs is treated the same as the indexes did: focusing on the amount of jobs accessible. They state that by focusing changes of the public transportation system in the underserved neighborhoods, implementations of new policies and services will be more effective at connecting workers with jobs.

An important conclusion about job access is made by Prud'homme et al. (1999) when attempting to model job access in metropolitan regions [19]. They suggests that the optimal size of a city is a function of the quality of its transportation planning. As cities grow they increase total jobs available but traffic congestion increases simultaneously. Therefore cities that are successful in combating congestion by having good transportation planning have a larger 'optimal' size and consequently are able to supply more jobs to typical residents. Prud'homme and Lee (1999) found a general link between the productivity of residents (unemployment rate per capita) and the number of jobs that residents have access to within 60 minutes.

2.4 Research questions

2.4.1 Key components of literature for this research

There is a consensus on the importance of commuting and therefore job accessibility in the analysis of transport poverty. But all the examined researches concerning transport poverty focus on the accessibility of all jobs. No differentiation is made between types of jobs even though people have different education levels and preferences. A person is therefore not equipped for or interested in all accessible jobs. Industrial jobs for example are not uniformly spread across all job locations. Most can be found in the outskirts of the city as is the case for city examined in this research Ghent.

Martens et al. (2019) provide insight into the importance of examining different groups separately since the used facilities can rank differently in importance. The supporting data for this can be found in the IDB for Flanders [20]. The examination of different groups should be extended to ranking the importance of accessibility to jobs of different eduction level requirements as a first. This would make the measurement of job accessibility more realistic.

The research of the Brookings Institute (2011) concerning job accessibility approach it in the same way as the indexes do. They provide metrics to compare job accessibility on metropolitan scale and examine the amount of accessible jobs.
Kaufman et al. (2015) provide insight into the possibilities of comparable metrics on a neighborhood level. Neighborhoods with lowest accessibility are identified and give policy makers the ability to address the failures of the transportation network in areas where it is needed.

Duvarci et al. (2015) provide insight into the importance of examining different policy alternatives using simulations. Showing policy makers the effect caused by the alternatives in clear cut metrics that are easily understandable makes ranking these more straightforward.

A summation is given of important components of the analysed literature that help shape this research of job accessibility.

- Differentiation between groups helps in identifying the needs of the transit network for specific groups
- A metric on a neighborhood or smaller level gives insight into the difference in accessibility in different parts of the city
- Changes in the transportation network should be simulated and measured with comparable metrics to facilitate policy making

2.4.2 Research questions

The researches that were analysed all define job accessibility from the perspective of a person. This is obvious when quantifying transport poverty since that is important on an individual level. But the difficulties arise when broad meaningful indexes are defined to describe transport poverty on a metropolitan level (or even neighborhood level). The differentiation within jobs is

left out in order to get to the metrics of job accessibility.
This research will therefore use the reverse approach. Job accessibility is examined from the perspective of the company. This makes sense for the city of Ghent since it has a few areas with high numbers of available jobs (see chapter 3). Examining the accessibility of the areas with a high number of available jobs for people (working there) could thus provide more insight into the failures of the transportation network for commuting.

Commuting abilities are expanded in the port of Ghent past simple bus routes as listed by Voka [21], the organization providing a network and representation for companies in Flanders. This research is therefore interested in the effect of the expansions of the transportation network for the employees in the port of Ghent. There is also a new railway line under development to connect the port of Ghent to the city [22]. The effect of this new train to connect employees to the port of Ghent is also examined in this research.

The accessibility of jobs is not only important for people that have a job but also for people looking for a job. The fact that unemployment is linked to the inability to reach jobs (Ades et al. 2016), imply that possible changes in the transit network provide a positive effect of accessibility for unemployed job seekers. On top of that, the port of Ghent has difficulties in filling in vacancies [22]. Therefore this research also provides insight in possible new improvements of the transit network (such as the new railway line and a change in bus route) and their effectiveness in connecting unemployed people with the port of Ghent.

Chapter 3

Methodology

This chapter presents the different methodologies used to answer the research questions. Firstly the used program Conveyal is explained together with the general description of the used metrics. This is followed by presenting the used data sources and the preparation of this data in order to be able to get the results.

3.1 Work method

3.1.1 Conveyal

Conveyal is a powerful analysis tool specifically designed to understand the accessibility of locations with multi-modal transportation networks [23]. Different research-backed accessibility metrics can be determined with the help from this tool. In other words, Conveyal helps in measuring and visualizing who can reach what, and how reliably. Conveyal uses colored areas of which the edges represent isochrones. The parameters that are needed for the analysis of the accessibility metrics, are stated and explained here.

- **Travel time cutoff** Limits how long a person can travel from the selected location and represents the edges of the visualised colored areas (normally set at 45 or 60 minutes).
- **Travel time percentile** Can mean different things at different percentiles. 5% means that a person times their departure as to minimize travel time while 75% may mean a person departing at a random time. The in-depth explanation for this interpretation is not given because the only percentile used is 5% in this research [24].

- **Access mode** Determines the "private" choice of displacement; walking, cycling or driving (normally set at walking).
- **Choice of transit modes** Determines the (partial) use of the public transportation network (normally set at the entire public transportation network)
- **Maximal amount of transfers** Determines how many transfer between vehicles a person is allowed to make (normally set at 3)

Another feature of Conveyal is the possibility to upload opportunity data sets. These data sets can be a list of coordinates each corresponding to a number representing the amount of jobs, supermarkets or anything else that can be found at those coordinates. This is an important feature because it helps in calculating the amount of opportunities that are accessible within a certain time (and setting) for any location within the analysed region. The opportunity data set can also be a shapefile. A shapefile contains coordinates of outlined areas on a map instead of single point coordinates. The opportunity data set tool forms the basis for the metric describing the difference in the number of people that can reach a location within a certain time.

The last important feature of Conveyal is the possibility to modify/extend the baseline network with new/changed routes/roads. These modifications can be used to make different scenarios representing different realities or city policies. These different scenarios are simulated and compared with the help of the metrics in order to measure the effect of changes in the transportation network.

3.1.2 Metrics of accessibility

These metrics describe the effect on the accessibility of the location caused by modifications to the public transit network or the road map. These changes are stored under different scenarios. The described metrics are measured with the help of Conveyal.

Visualisation

A first important check of the effect of modifications is visually. Big changes in accessibility are easily spotted on a map and therefore a map is always provided whenever a comparison of scenarios is made in this research.

Difference in the number of people that can reach the location within a certain time

Using opportunity data sets representing different groups of people across the region, it is calculated how many of a group can reach the selected location within a certain time. When two scenarios are compared, the difference in the number of people that can reach the location within a certain time easily represents a metric for the regional effect of certain modifications on the relevant group. This is much more difficult to do when the effects are only shown on a map, indicating the value of this metric.

Remark that although this metric is easy to understand, it is heavily dependent on the set travel time cutoff (and therefore fluctuations). If the whole opportunity data set is accessible within the set travel time cutoff for both scenarios, the difference in the number of people that can reach the location within a certain time is zero. The effect of the modifications may only be visible with this metric with a lower (or higher) travel time cutoff.

Transportation time reduction

The transportation time reduction forms the most unambiguous metric. The only downside being that it is time intensive to accumulate. The transportation times for both scenarios can only be examined for one location at a time. Therefore aggregated points that represent areas with a high number of opportunities, are needed. These points are made in a subsequent section of this chapter. Combining these transportation time reductions as an average for all aggregated points of an opportunity data set makes this metric comparable for multiple scenarios.

Difference in number of transfers

Transfers in the public transit network can be perceived as negative for two reasons. Firstly, transfers can be missed due to delays in the public transportation network. This makes a person more likely to reach its destination in time if the number of transfers is lower. Secondly, transfers can also cause a person to relax less during commuting because they need to move and wait more. Therefore lowering the amount of transfers a person has to take, should be considered when proposing changes in the network and forms the reason for this metric.

3.2 Exploration of open-source data

The open source library built on top of the Python programming language, called Pandas is used as a data analysis and manipulation tool of the shape- and csv-files containing the different data sets of this research. GeoPandas extends the data types used by pandas to allow spatial operations on geometric types. This will help in the exploration of open-source data.

3.2.1 GTFS data

The General Transit Feed Specification (GTFS) is a data specification that allows public transit agencies to publish their transit data in a format that can be consumed by a wide variety of software applications. De Lijn, the public transit agency of Flanders, uses this format as well [25]. Since the research is limited to Ghent and the region around it, the GTFS data of Flanders is cropped to keep all routes with a stop within the same bounds as the analysed region.

3.2.2 OpenStreetMap

Geographical data, such as streets, of the analyzed region are needed. These maps can be imported by OpenStreetMap (OSM), a map of the world built largely from scratch by volunteers and free to use under an open license. To obtain OSM data from a particular area, Geofabrik can be used. Geofabrik is an open data source that allows someone to extract and process free geodata from all over the globe [26]. This is done for the bounded region that is analysed.

3.2.3 Overpass-turbo

Gathering data of the possible destination nodes, except job locations, happens with overpass-turbo. Overpass-turbo (overpass-turbo.eu) is a web-based data mining tool for OpenStreetMap. It runs any kind of Overpass API query and shows the results on an interactive map. The results can be downloaded as GeoJSON files. This query can be used for example to collect the locations of all supermarkets in the analysed region.

3.2.4 Statistical sectors

A statistical sector is the smallest territorial unit used in Belgium. It is created from a division of the municipalities and former municipalities by Statbel (General Direction of Statistics -

Statistics Belgium) for the dissemination of statistics at a more detailed level than the municipal level [27]. Geo (geo.be) is a web-based visualisation of the statistical sectors of Belgium on top of the map of Belgium. These statistical sectors are available to download as shapefiles that can be analysed and manipulated with GeoPandas.

3.2.5 Travel motives

In order to analyse the travel motives of people, the most important data-sets are the IDB-tables (short for Investigation of Displacement Behavior) [20]. The tables representing the distribution of the average amount of displacement per person per day by their status and motive (at page 110 of the IDB-tables) are visualised in the appendix. The displacement behavior described as *work transportation* represent the displacement of a person FOR their job and not TO their job. This will be left out since it has no relevance to transport poverty. The column *work* represent the displacement a person undergoes to get to their job.
The largest differences between statuses are found in motives such as work, education and bringing/picking up someone/something. Motives as shopping and recreation (and by extend services) are of equal importance for the various statuses. When looking solely at the status of a person, the clerks travel the most per day while incapacitated people travel the least as seen in figure A.3. When looking solely at motivation of displacement, shopping is the most important with 25% of all displacements. Working is only on the fifth place with 12% as seen in figure A.4. This is due to the travel motive of working only being relevant for the working population (around 40% of the population of Belgium [28]) while shopping is relevant for the whole population.

Travel motives of working populations

Since the scope of this research is focused on the accessibility of work locations and thus the travel motive of work, the importance of this travel motive can only be truly stated when the working population is examined separately.
This gives the pie chart in figure 3.1 for the motives of transportation of an average worker. It is clear that the travel motive of work is the most important for people with jobs. The second most important motive is shopping. In this research the travel motive of shopping is limited to going to the supermarket since this location's accessibility is the most relevant in tackling transport poverty.

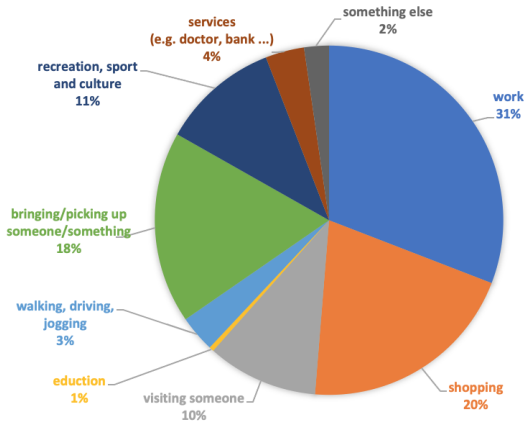


Figure 3.1: Distribution of transportation motives for average worker

Accessibility of supermarkets

In the appendix, figure A.5 shows the regional analysis for supermarkets and it is clear the city of Ghent has no problems with the accessibility of them. Since the other "needed" locations for an average worker only become less important and most of them can be found within the city at reasonable travel times (as can be seen in the other regional analysis in the appendix), the most defining location of the work population in the context of transport poverty is the workplace. For that reason commuting data is examined.

3.2.6 Commuting data

Commuting behavior to Ghent is attainable with the data from Census [29]. This data contains the commuting from and to every statistical sector in Belgium. The data set has a row for every possible combination of statistical sectors and therefore could be presented as a matrix with the statistical sector of the household and of the job location as row and column number, respectively. The element on place i, j represent the number of people that live in statistical sector i and work in statistical sector j. This data is described as the commuting data in short and helps to understand commuting patterns.

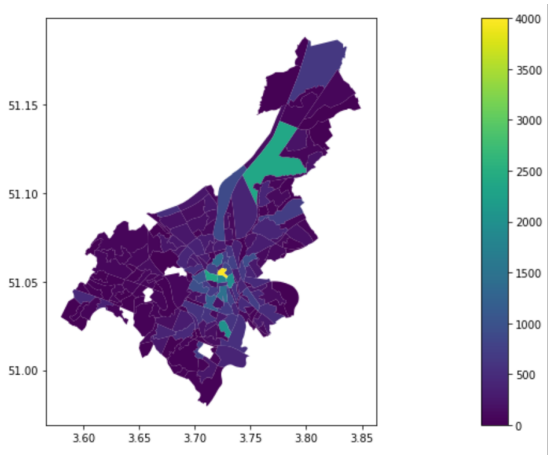
The total amount of people employed in Ghent is estimated at 141 572. 45.25% (or 61 228) of those are residential in Ghent and 49.94% (or 70 707) live elsewhere in East Flanders (the province of which Ghent is the capital). Meaning most people with a job in Ghent come from within the analysed region.

Employment attraction poles of Ghent

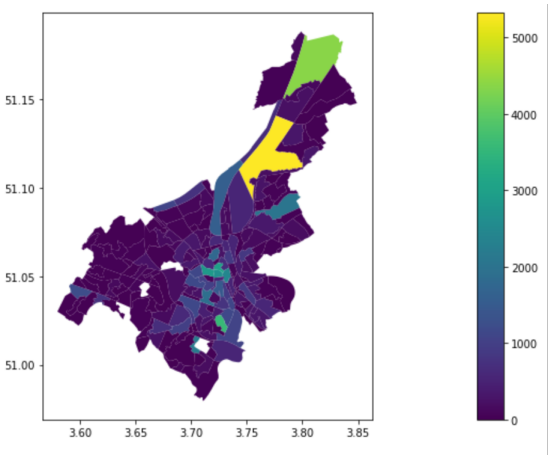
If the commuting data is summed over all rows, a new data set is formed containing the amount of people that work in each statistical sector. This is visualised for Ghent in figure 3.2c and can be used to find the statistical sectors in Ghent with the most job opportunities, called the employment attraction poles. There are four statistical sectors that emerge as employment attraction poles; two in the port of Ghent (yellow and green sector in the north of Ghent), one in the city center (yellow sector with green ones around it) and one south of the city center. This last one is the statistical sector that encompasses the academic hospital of Ghent (UZ Gent). The statistical sector Texaco (yellow) and Rostijne (green) in the port of Ghent encompass the corporations Volvo Cars and ArcelorMittal, respectively. These companies have the largest number of employees in the port of Ghent [30].

Figure 3.2a and 3.2b show the amount of people that work in each statistical sector who are and are not residential in Ghent, respectively. In figure 3.2a, the colors of the neighborhoods transition more uniformly than in figure 3.2b. This indicates a more uniform distribution of job locations of people residential in Ghent. People residential in Ghent are also employed more in the city center while people not residential in Ghent are employed more in the port of Ghent. But within the port of Ghent there are differences as well. The statistical sector Texaco has a lot more employees in Ghent than Rostijne.

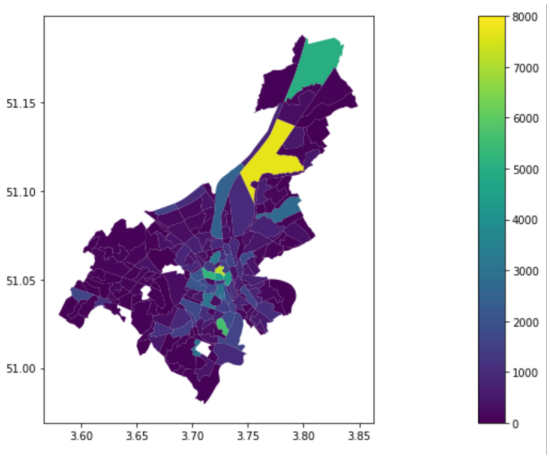
Since most of the transit routes pass through the city center while the port of Ghent has only a few [31], the accessibility of the port of Ghent forms an interesting subject where the following chapters will delve deeper into. But before that is possible, information is needed about the location of the statistical sectors and its employees.



(a) Number of people per statistical sector employed and residential in Ghent



(b) Number of people per statistical sector employed but not residential in Ghent



(c) Number of people per statistical sector employed in Ghent

Figure 3.2: Number of people per statistical sector employed in Ghent

Port of Ghent

The port of Ghent is the largest neighborhood of Ghent making it impractical analysis in its whole. To simplify the research, the accessibility of the port of Ghent is measured for two locations; the entrance of Volvo Cars and ArcelorMittal. As stated before, these are the biggest companies of the port of Ghent [30] and lie in the two statistical sectors with the highest number of employees of the port of Ghent. For both of these statistical sectors separately, the commuting data is used to visualise the statistical sectors where their respective employees live. This can then be used to pin-point the locations with a high number of employees in their vicinity, called aggregation points. These aggregation points are needed for the metric of travel time reduction and visualised in figures 4.3a and 4.3b for employees of Texaco and Rostijne respectively. The

shapefile of the statistical sectors of Ghent can be extended with two columns containing the number of employees of Texaco and Rostijne that are residential in the corresponding statistical sector. These are used in chapter 4. In the appendix, figures A.6 and A.7 give the visualisation of the shapefile in Conveyal. The dots each represent a person. The spreading of the persons is uniformly across the surface of the statistical sector since only the residing statistical sector and not the exact location is known. This shapefile is needed for the metric of difference in the number of people that can reach the location within a certain time.

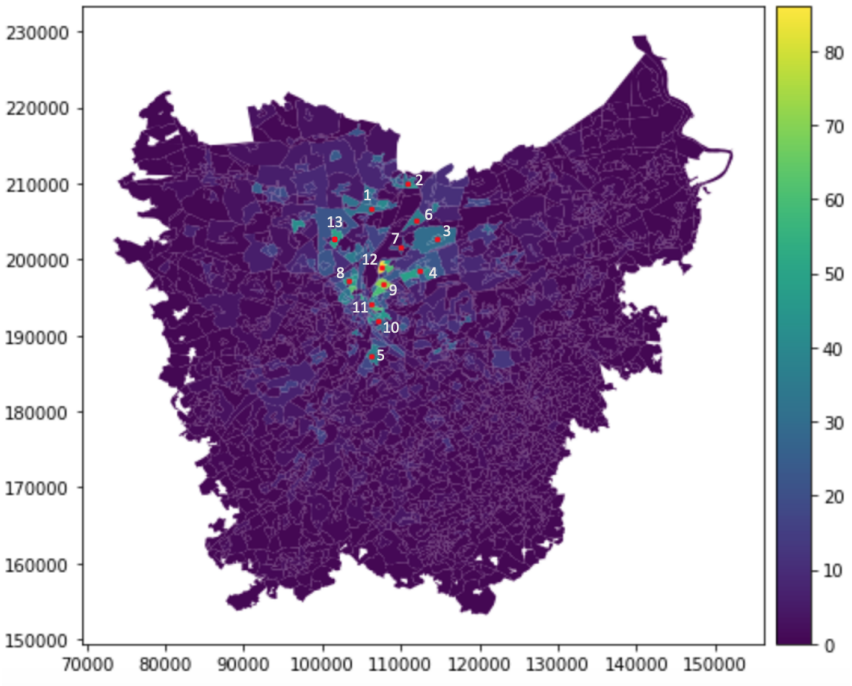


Figure 3.3: Aggregation points for employees of Texaco

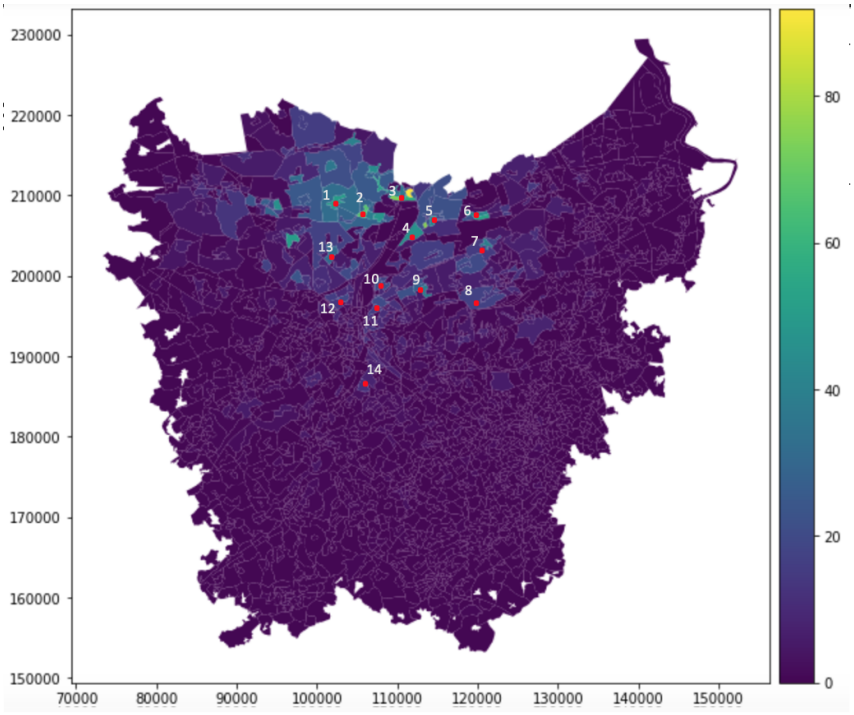


Figure 3.4: Aggregation points for employees of Rostijne

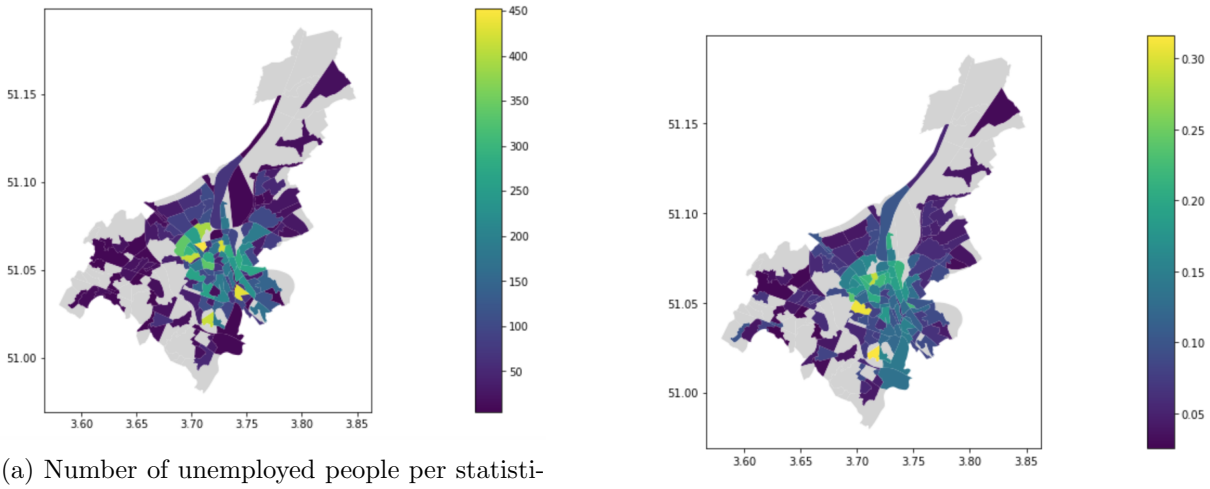
3.2.7 Unemployment data

As stated before, the companies in the port of Ghent have difficulties filling in all job openings and therefore the unemployed jobseekers form an important group to analyse [22]. The data of this group is available per statistical sector in Ghent and can therefore also be used to make aggregation points with high unemployment (rates).

In Ghent in 2018 an estimated 14 581 people were unemployed and looking for a job [32]. In that same year, Ghent had a working population of about 113 096. This means that there was 11.42% of the possible workforce not being used, called an unemployment rate of 11.42%. In comparison, the unemployment rate of Belgium in 2018 was estimated at 7.63% [28].

In figure 3.5a and 3.5b, the number of unemployed people and the unemployment rate per statistical sector of Ghent are shown, respectively. This can be used to pin-point the aggregation points with a high number of unemployed people or a high unemployment rate in their vicinity. This is visualised in figure 5.3. The underlying map here represents the accessibility of other facilities important for unemployed people. The shapefile of the statistical sectors of Ghent is extended with a column containing the number of unemployed people that are residential in the corresponding statistical sector. This data-set is used in chapter 5. In the appendix, figure A.8 gives the visualisation of the shapefile in Conveyal. The dots each represent a person. The

spreading of the persons is uniformly across the surface of the statistical sector since only the residing statistical sector and not the exact location is known. This shapefile is needed for the metric of difference in the number of people that can reach the location within a certain time.



(a) Number of unemployed people per statistical sector

(b) Unemployment rate per statistical sector

Figure 3.5: Unemployment per statistical sector in Ghent

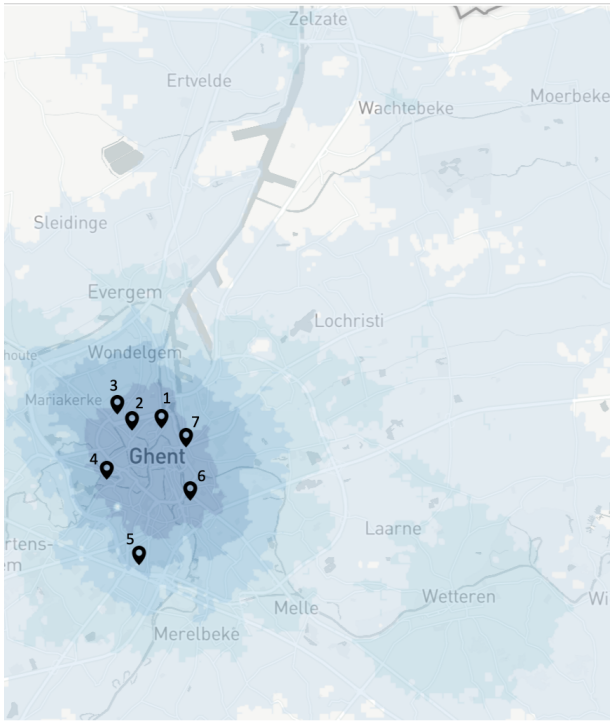


Figure 3.6: Aggregation points of unemployment in Ghent

Chapter 4

Effects of existing additions to the public transportation network for the Port of Ghent

As described in chapter 3, the port of Ghent is narrowed down to two companies namely *Volvo Cars* and *ArcelorMittal*. In this chapter the effectiveness of existing additions to the public transportation network are measured in the metrics of accessibility as described in chapter 3. These metrics are elaborated further on. Since the project for a new railway line has started that would better connect the port of Ghent to the city center, the effectiveness of this extra railway line are measured as well.

This chapter begins with a visualisation of all the existing additions to the transportation network and the accessibility these provide for the statistical sector of Texaco (Volvo Cars) and Rostijne (ArcelorMittal), separately. Afterwards, the metrics of accessibility are provided for an additions to the public transportation network compared to the transportation network without the addition. This is again done for all additions to Texaco and Rostijne separately.

In this chapter, all figures are made with the help of Conveyal. For each analysis the parameters are set at a transportation time of maximal 60 minutes and a travel time percentile of 5%. The red colored areas on the figures represent the locations reachable (from the location marker) with the additional transportation method (marked in a blue line) also at the disposal.

4.1 Visualisation of the existing transportation network

The additions to the existing transportation network are shown in figure 4.1. These additions include the five private bus routes of Volvo Cars and ArcelorMittal, the bus routes of Max Mobiel for the port of Ghent and the ferry. These are the addition that are stated by Voka [21]. Whence a bus route has a stop within the analysed borders of the map, this stop and all following stops are included in the modification in Conveyal. The routes do not follow the streets but the time between the stops is set as if they would. This does not form an extra limitations for the interpretation of the data since traffic has been excluded from this research.

In figures 4.2a and 4.2b, the accessibility of Volvo Cars and ArcelorMittal within 60 minutes caused by the total existing transportation network is visualised. The effect of the additions can be partly seen here when looking at the added routes and the blue zone they emit along their path. The metrics of the following sections are dedicated to understand how large the effect of each one of these additions actually is.

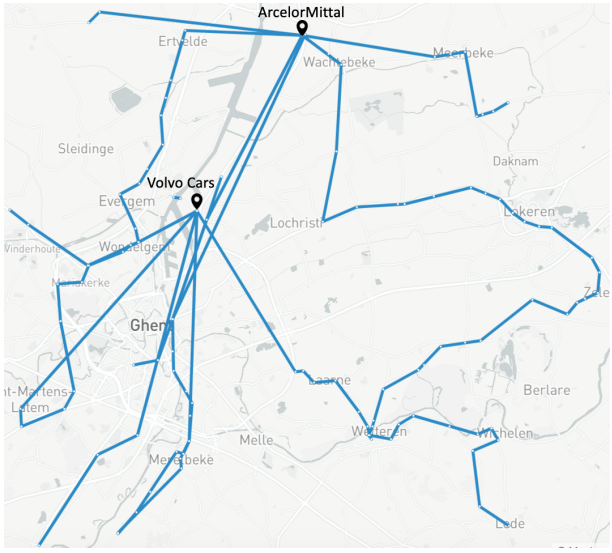
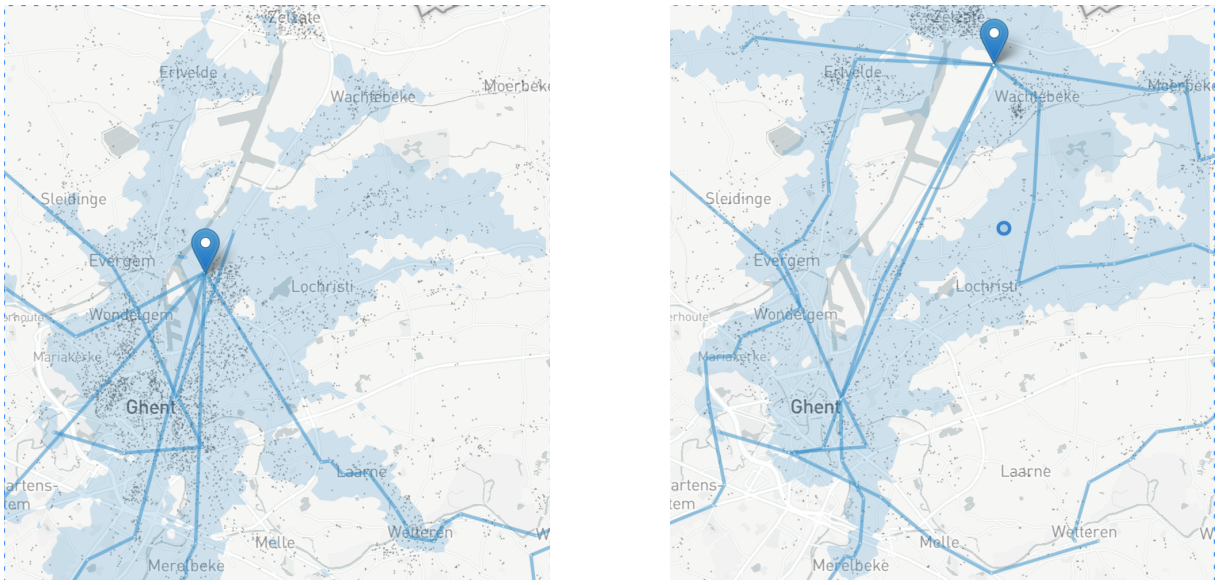


Figure 4.1: Visualised existing additions to transportation network

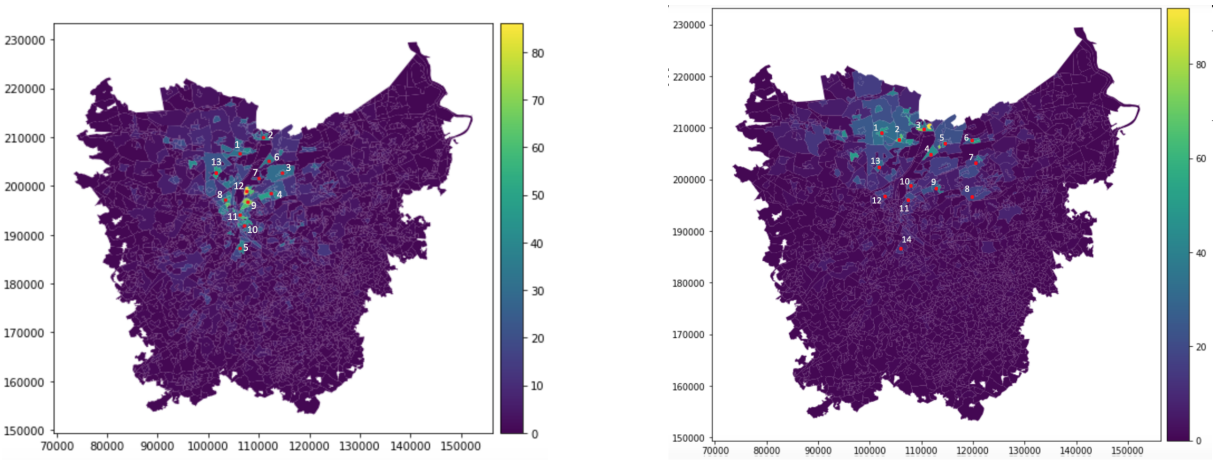


(a) Accessibility of Volvo Cars

(b) Accessibility of ArcelorMittal

Figure 4.2: Accessibility of locations within 60 minutes

For clarity, the aggregation points of residential areas for Texaco and Rostijne (that were mentioned in chapter 3) are again shown here in figure 4.3a and 4.3b. Tables 4.2, 4.4, 4.6,4.8,5.2 and 5.4 in this chapter will refer to these points with their codes in order to better understand the changes in travel time. The codes are shown in table 4.1. These codes represent the estimated direction and distance as the crow flies of each aggregated point from Texaco and Rostijne, respectively. For example the code *NNW8.1* for Texaco's location 1 tells that point 1 lies 8.1 kilometers to the north-northwest of the entrance of Volvo Cars. The name of the statistical sector or municipality that the point is located in, are also shown. These names will be used for the interpretation of the measurements.



(a) Texaco (b) Rostijne

Figure 4.3: Aggregation points of residential areas

Table 4.1: Number of aggregated points and their corresponding statistical sector or municipality and code

Number	Texaco		Rostijne	
	Name	**Code**	**Name**	**Code**
1	Ertvelde	NNW8.1	Oosteeklo	W9.9
2	Zelzate	NNE10.3	Ertvelde	W5.9
3	Zaffelare	ENE8.0	Zelzate	NW2.2
4	Lochristi	ESE5.0	Sint-Kruis-Winkel	SSW3.1
5	Merelbeke	S11.8	Wachtebeke	ESE2.3
6	Sint-Kruis-Winkel	NE7.1	Moerbeke	E7.1
7	Desteldonk	NE2.7	Eksaarde	ESE9.4
8	Wondelgem	SW3.1	Heiende	SE13.7
9	Lourdes	SSE2.8	Lochristi	S9.7
10	Vogelhoek	SSE8.4	Oostakker	SSW10.1
11	Dampoort	SSW5.3	Dampoort	SSW15.1
12	Oostakker	SE0.9	Wondelgem	SW12.9
13	Sleidinge	WNW6.1	Sleidinge	WSW12.0
14			Merelbeke	SSW21.9

4.2 Effect of the ferry

The first addition that is examined is the ferry. This ferry connects Volvo Cars at the east side of the canal to the west side. Since the ferry is owned by the government, its effects are not limited to the accessibility of employees of Volvo Cars but extend to the public. Therefore its effects are also examined for the accessibility of ArcelorMittal.

4.2.1 Effect of the ferry for Texaco

In figure 4.4, the route of the ferry (little blue line) is shown together with the extra areas that can reach Texaco within 60 minutes (in red) with the ferry as part of the transportation network. The improvements lie on the west side of the canal.

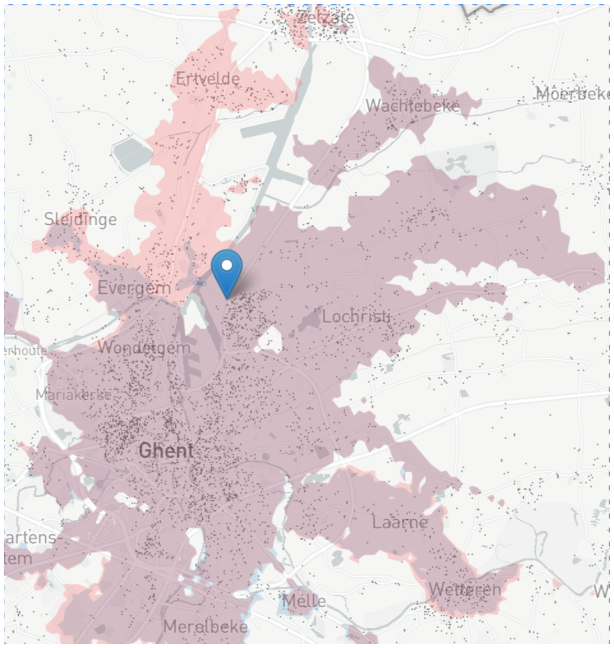


Figure 4.4: Visualised effect of the ferry for Texaco

Transportation time reduction

The total number of people that are able to reach the site of Volvo Cars with the existing transportation network is estimated at 3 477. Even though this number should be the same when examining all the different addition to the transportation network, it is not. The reason for the fluctuation of this number is due to a limitations to the number of simulated schedules in Conveyal. The number of people that can reach Volvo Cars within 60 minutes without the

ferry as part of the transportation network is estimated at 3 110. Therefore the amount of extra employees that can reach Volvo Cars within 60 minutes is estimated at 367. Which is a marginal increase of 11.80%.

On the other hand an important metric is the travel time difference it bodes for the aggregated locations of employees. This is visible in table 4.2. For completeness the travel time by car from these locations is also mentioned as an upper limit for the transportation time since most locations are still fasted reached with a car. Four of the thirteen locations have a noticeable difference in travel time, going as far as time reductions of 34.21%. Which gives an average travel time improvement of 6.27% for all thirteen locations.

Table 4.2: Travel time differences effect of ferry for Texaco (in min), location codes can be found in table 4.1

Location	**With**	**Without**	**Difference**	**Time reduction (in %)**	**Only car**
NNW8.1	45	71	26	34.21	19
NNE10.3	56	79	23	29.11	19
ENE8.0	-	-	-	0	-
ESE5.0	-	-	-	0	-
S11.8	-	-	-	0	-
NE7.1	-	-	-	0	-
NE2.7	-	-	-	0	-
SW3.1	43	47	4	8.51	18
SSE2.8	-	-	-	0	-
SSE8.4	-	-	-	0	-
SSW5.3	-	-	-	0	-
SE0.9	-	-	-	0	-
WNW6.1	56	62	6	9.68	26

Change of average number of transfers

The number of transfers that employees need to take forms another important metric as described in chapter 3. Taking less transfers to reach the locations within 60 minutes is better. Table 4.3 shows the effect of the ferry on the number of transfers needed to reach Texaco within 60 minutes. The percentage of people that can reach Texaco without transfers drastically lowers

with almost 15%. The estimated mean number of transfers with the ferry as an option is 0.5049. The estimated mean number of transfers without the ferry as an option is 0,3294. This is an increase of 53.28% by the addition of the ferry.

Table 4.3: Transfer differences effect of ferry for Texaco

	Number of transfers	0	1	2	3
With ferry	**Number of people (CUSUM)**	2 003	3 210	3 487	3 487
	Number of people (distr)	2 003	1 207	277	0
	Percentage of people	57.44%	34.61%	7.94%	0
Without ferry	**Number of people (CUSUM)**	2 141	2 846	2 985	2 985
	Number of people (distr)	2 141	705	139	0
	Percentage of people	71.72%	23.62%	4.66%	0

4.2.2 Effect of the ferry for Rostijne

In figure 4.6, the route of the ferry to Texaco (blue line) is shown. No extra areas can reach ArcelorMittal with this expansion to the network.

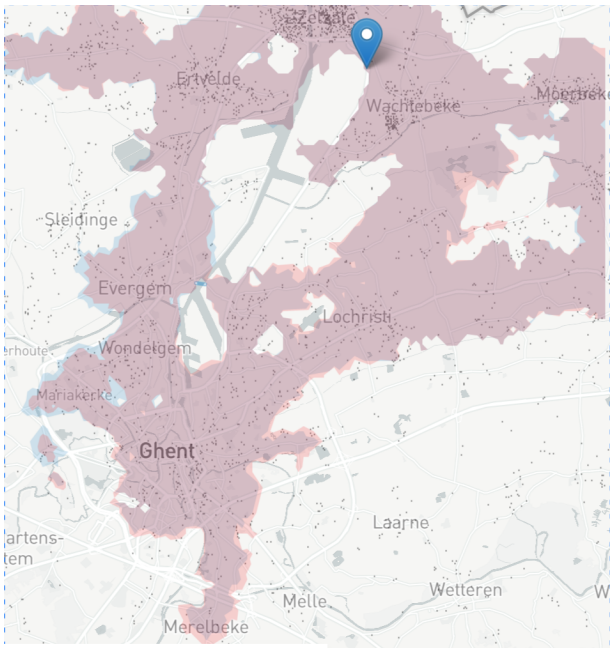


Figure 4.5: Visualised effect of the ferry for Rostijne

Their are not explicitly more people that can reach ArcelorMittal within 60 minutes nor is their a difference in travel time measurable. On top of that the number of transfers is not altered.

Therefore no effect is felt for employees of ArcelorMittal by adding the ferry to the transportation network.

4.2.3 Conclusion for the effectiveness of the ferry

The ferry's importance lies in the absence of a bridge close to its location and it is able to connect an otherwise difficult to reach location from the site of Volvo Cars. And just as bridges form important connection in the transportation network, so does this ferry.

Firstly, the importance of the ferry is suggested by the increase of 11.80% in employees of Volvo Cars that can reach the site within 60 minutes using only public transits including the ferry.
Secondly, the travel time reductions induced by the presence of the ferry, form an important improvement. For example, the employees in Ertvelde have a travel time reduction of more than 30%. This shows that it effectively enables employees to reach the work place faster. Another example is found in Wondelgem where employees now have two option to get to the site of Volvo Cars. One includes two bus rides with a transfer at Ghent Dampoort which takes 47 minutes. The second one includes taking a bus to the ferry and then taking the ferry which takes 43 minutes. Although this is only a travel time reduction of a bit more than 8%, the bus stop is located 170 meters from the ferry stop, showing the cooperation between the public transit company, De Lijn, and the ferry.
Thirdly, its benefits also extend to employees that go by car to the site since the ferry is able to transport cars as well.
Lastly, the ferry's importance is not limited by its effect on commuting to Volvo Cars but other transportation motives may also be positively influenced by the ferry. These motives are not further investigated in this thesis.

The benefits of the ferry on commuting are not felt by the employees of ArcelorMittal since this site lies close to the bridge of Zelzate and the bridge of the E34 highway across the canal.

4.3 Effect of the Max Mobiel routes to the port of Ghent

4.3.1 Effect of Max Mobiel to Texaco

In figure 4.6, the route of Max Mobiel to Texaco (blue line) is shown together with the extra areas that can reach Texaco within 60 minutes (in red) with Max Mobiel as part of the transportation network. The small improvements lie to the east and west of Ghent.

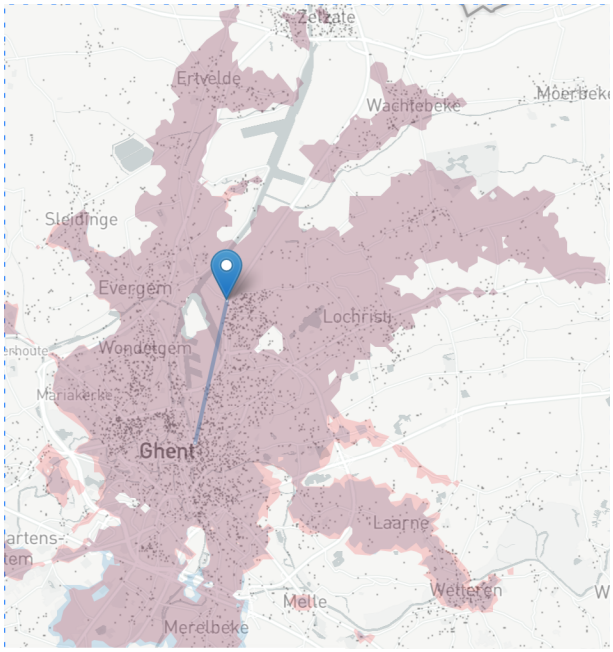


Figure 4.6: Visualised effect of the max mobiel route to Texaco

Transportation time reduction

The amount of extra employees that can reach Volvo Cars within 60 minutes with Max Mobiel as part of the transportation network is estimated at 76. This is a marginal increase of 2.19%.

The effect on the travel time to Texaco from the thirteen locations by Max Mobiel are visible in table 4.4. Only two locations are altered by the presence of Max Mobiel, which are the locations close to the train station Dampoort, with a time reduction of up to 20.59%. This gives an average travel time improvement of 2.21% for all thirteen locations.

Table 4.4: Travel time differences effect of Max Mobiel to Texaco (in min), location codes can be found in table 4.1

Location	With	Without	Difference	Time reduction (in %)	Only car
NNW8.1	-	-	-	0	-
NNE10.3	-	-	-	0	-
ENE8.0	-	-	-	0	-
ESE5.0	-	-	-	0	-
S11.8	-	-	-	0	-
NE7.1	-	-	-	0	-
NE2.7	-	-	-	0	-
SW3.1	-	-	-	0	-
SSE2.8	45	49	4	8.16	16
SSE8.4	27	34	7	20.59	11
SSW5.3	-	-	-	0	-
SE0.9	-	-	-	0	-
WNW6.1	-	-	-	0	-

Change of average number of transfers

Table 4.5 shows the effect of Max Mobiel on the number of transfers needed to reach Texaco within 60 minutes. No big changes in the percentages of people are visible. The estimated mean number of transfers with Max Mobiel as an option is 0.5049. The estimated mean number of transfers without Max Mobiel as an option is 0.4537. This is an increase of 11.28% by the addition of the bus of Max Mobiel.

Table 4.5: Transfer differences effect of Max Mobiel to Texaco

	Number of transfers	0	1	2	3
With Max Mobiel	**Number of people (CUSUM)**	2 003	3 210	3 487	3 487
	Number of people (distr)	2 003	1 207	277	0
	Percentage of people	57.44%	34.61%	7.94%	0
Without Max Mobiel	**Number of people (CUSUM)**	2 119	3 237	3 464	3 464
	Number of people (distr)	2 119	1 118	277	0
	Percentage of people	61.17%	32.27%	6.55%	0

4.3.2 Effect of Max Mobiel to Rostijne

In figure 4.7, the route of Max Mobiel to ArcelorMittal (blue line) is shown together with the extra areas that can reach Rostijne within 60 minutes (in red) with Max Mobiel as part of the transportation network. The small improvements lie to the east and west of Ghent.

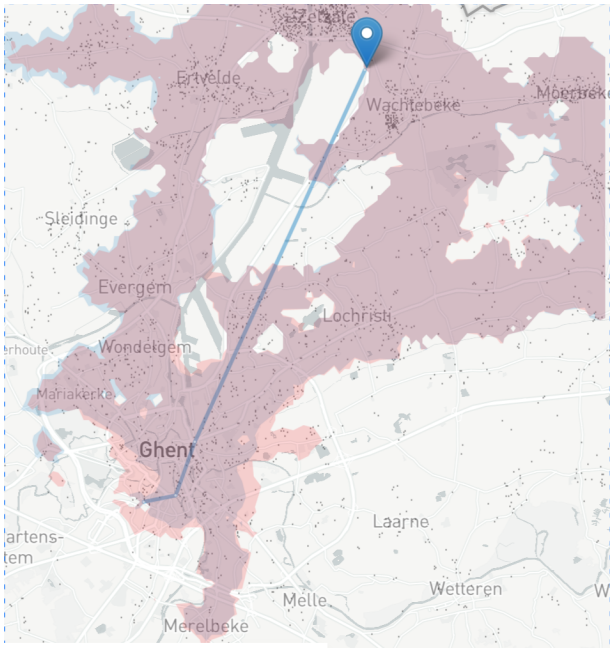


Figure 4.7: Visualised effect of the max mobiel route to Rostijne

Transportation time reduction

The amount of extra employees that can reach ArcelorMittal within 60 minutes with Max Mobiel as part of the transportation network is estimated at 28. This is a marginal increase of 1.35%. But none of the 14 aggregated location points have a measurable time reduction nor are the number of transfers altered.

4.3.3 Conclusion for the effectiveness of Max Mobiel

Max Mobiel is an independent company that can offer commuting employees an alternative to the existing public transit. Volvo Cars and ArcelorMittal employ Max Mobiel to facilitate commuting since both sites are sometimes difficult to reach with public transportation alone at the hour the employee's shift begins. Max Mobiel provides their service only when employees need it (or in other words when the public transit is not available) which means their benefit to the

transportation network comes from their flexibility in working hours. The measurements provide no insight in flexibility since the hour of departure is not taken as an important parameter.

When looking at the improvements to the accessibility of Texaco, firstly only the employees of Texaco residing at Dampoort have a significant travel time reduction of about 20% when using Max Mobiel. This is due to the number of stops and associated detour a regular bus follows before an employee is dropped of at the site of Volvo Cars. Max Mobiel, on the other hand, has its stop right at that location and then goes straight to the site of Volvo Cars.
Secondly the percentage of employees that do not need to transfer in order to get to the site drops with the inclusion of Max Mobiel. This comes from the fact that the travel time reduces for people if they transfer to Max Mobiel in Dampoort instead of staying on the same bus.

No noticable difference occur for the accessibility of ArcelorMittal with Max Mobiel as an option. The reason for this is the lower amount of employees located in Ghent in comparison to those of Volvo Cars and the option of taking the private bus of ArcelorMittal at Dampoort. Since ArcelorMittal still colaborates with Max Mobiel, its benefits are probably only applicable to low amount of employees and may come from other factors then shorter travel times (such as comfort). In this research they are just not possible to display in the current settings other than the red outline in and around Ghent in figure 4.7.

4.4 Effect of the private busses

For the statistical sector of Texaco the effect of the private busses of Volvo Cars are examined and for the statistical sector of Rostijne the effect of the private busses of ArcelorMittal are examined.

4.4.1 Effect of the private busses of Volvo Cars to Texaco

In figure 4.8, the routes of the five private busses (blue lines) are shown together with the extra areas that can reach Texaco within 60 minutes (in red) with the private busses as part of the transportation network. The improvements lie in the areas around the bus routes outside of Ghent.

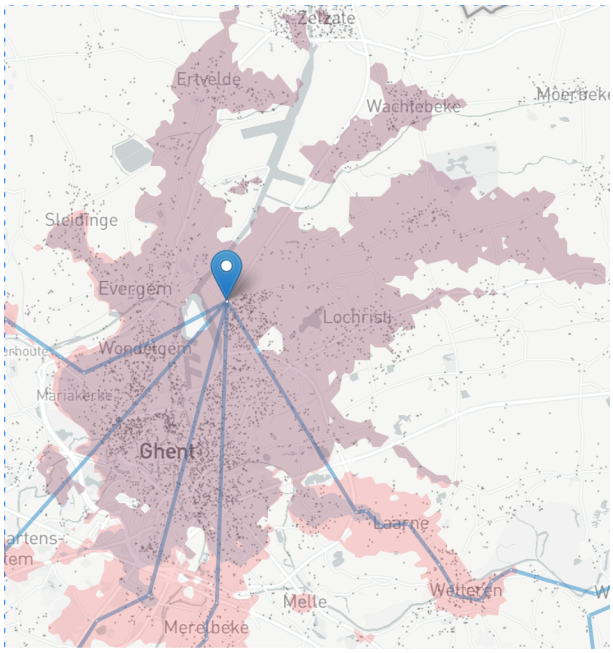


Figure 4.8: Visualised effect of the private busses of Volvo Cars

Transportation time reduction

The amount of extra employees that can reach Volvo Cars within 60 minutes with the private busses of Volvo as part of the transportation network is estimated at 391. This is a marginal increase of 12.28%.

The effect on the travel time to Texaco from the thirteen locations are visible in table 4.6. Two locations are altered by the presence of the private busses with a time reduction of up to almost 30% for employees residing in Merelbeke. This gives an average travel time improvement of 2.93% for all thirteen locations.

Table 4.6: Travel time differences effect of the private busses to Volvo Cars (in min), location codes can be found in table 4.1

Location	With	Without	Difference	Time reduction (in %)	Only car
NNW8.1	-	-	-	0	-
NNE10.3	-	-	-	0	-
ENE8.0	-	-	-	0	-
ESE5.0	-	-	-	0	-
S11.8	49	69	20	28.99	19
NE7.1	-	-	-	0	-
NE2.7	-	-	-	0	-
SW3.1	40	44	4	9.09	18
SSE2.8	-	-	-	0	-
SSE8.4	-	-	-	0	-
SSW5.3	-	-	-	0	-
SE0.9	-	-	-	0	-
WNW6.1	-	-	-	0	-

Change of average number of transfers

Table 4.7 shows the effect of the private busses on the number of transfers needed to reach Texaco within 60 minutes. A little increase of 3.61% is present in the percentage of people able to reach Texaco within 60 minutes without transfers with the private busses as part of the network. The estimated mean number of transfers with the private busses as an option is 0.5049. The estimated mean number of transfers without the the private busses as an option is 0.5425. This is a reduction of 6.93% by the addition of the private busses.

Table 4.7: Transfer differences effect of private busses to Volvo Cars

	Number of transfers	0	1	2	3
With private busses	**Number of people (CUSUM)**	2 003	3 210	3 487	3 487
	Number of people (distr)	2 003	1 207	277	0
	Percentage of people	57.44%	34.61%	7.94%	0
Without private busses	**Number of people (CUSUM)**	1 709	2 936	3 175	3 175
	Number of people (distr)	1 709	1 227	239	0
	Percentage of people	53.83%	38.65%	7.53%	0

4.4.2 Effect of the private busses of ArcelorMittal to Rostijne

In figure 4.9, the routes of five of the six private busses (blue lines) are shown together with the extra areas that can reach Texaco within 60 minutes (in red) with the private busses as part of the transportation network. One private bus route is not shown since it has no stops in the analysed region. The improvements by the private busses of ArcelorMittal lie all around the region and in the areas where a lot of employees are residential.

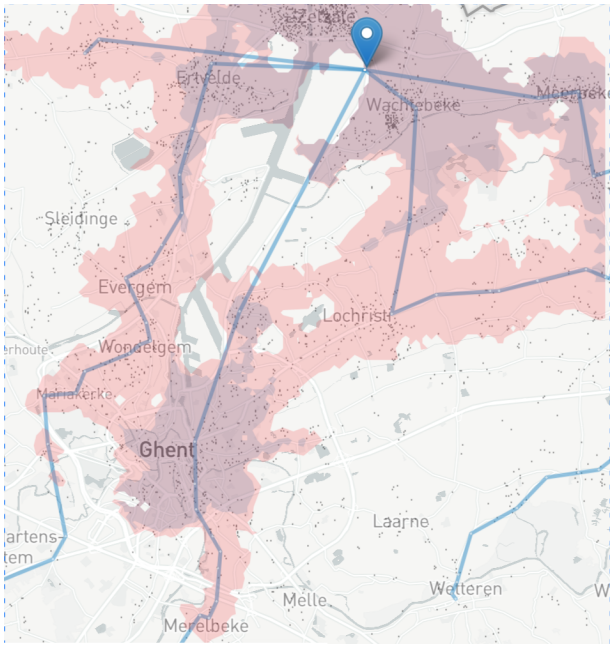


Figure 4.9: Visualised effect of the private busses of ArcelorMittal

Transportation time reduction

The amount of extra employees that can reach ArcelorMittal within 60 minutes with the private busses as part of the transportation network is estimated at 746. This is a marginal increase of 54.14%.

The effect on the travel time to Rostijne from the fourteen locations are visible in table 4.8. Only two locations are not altered by the presence of the private busses. All the other locations have almost all high time reduction with the private busses as part of the transportation network going as high as almost 60%. This gives an average travel time improvement of 33.67% for all fourteen locations.

Table 4.8: Travel time differences effect of the private busses to ArcelorMittal (in min), location codes found in table 4.1

Location	With	Without	Difference	Time reduction (in %)	Only car
W9.9	36	61	25	40.98	16
W5.9	29	54	25	46.30	11
NW2.2	24	35	11	31.43	6
SSW3.1	22	41	19	46.34	14
ESE2.3	28	48	20	41.67	21
E7.1	35	87	52	59.77	21
ESE9.4	35	70	35	50	20
SE13.7	30	55	25	45.45	18
S9.7	52	59	7	11.86	19
SSW10.1	44	74	30	40.54	19
SSW15.1	62	79	17	21.52	22
SW12.9	49	76	27	35.53	26
WSW12.0	-	-	-	0	-
SSW21.9	-	-	-	0	-

Change of average number of transfers

Table 4.9 shows the effect of the private busses on the number of transfers needed to reach Rostijne within 60 minutes. An increase of 5.09% is present in the percentage of people able to reach Rostijne within 60 minutes without transfers with the private busses as part of the network. The estimated mean number of transfers with the private busses as an option is 0.1314. The estimated mean number of transfers without the private busses as an option is 0.1748. This is a reduction of 24.83% by the addition of the private busses.

Table 4.9: Transfer differences effect of private busses to ArcelorMittal

	Number of transfers	0	1	2	3
With private busses	**Number of people (CUSUM)**	1 856	2 124	2 124	2 124
	Number of people (distr)	1.856	279	0	0
	Percentage of people	87.38%	13.14%	0	0
Without private busses	**Number of people (CUSUM)**	1 134	1 374	1 378	1 378
	Number of people (distr)	1 134	240	4	0
	Percentage of people	82.29%	17.42%	0.03%	0

4.4.3 Conclusion for the effectiveness of the private busses

The private busses are designed to make the company's site easier accessible for people that do not want or are not able to use a car. These locations are found further away from the site, not in cities and not on main connection roads to the site. The private busses of ArcelorMittal are estimated to able to connect 54.14% more employees to the site within 60 minutes. Volvo Cars, on the other hand, is able to increase the number of employees that can reach their site within 60 minutes with 12.38%. On top of that, 12 of the 14 locations of employees of ArcelorMittal have an improved travel time with some big time reduction (up to almost 60%). The same can only be said of 2 of the 13 locations of Volvo Cars with a max time reduction of almost 30%. Therefore one might conclude that ArcelorMittal has far more effective private busses, but the underlying reasons for this success should be clarified.

The success of the private busses of ArcelorMittal is benefited by two main reasons; their worse positioning in Ghent and their scattered employees across the analysed region. Both of these reasons and how they influence the success of the private busses are elaborated here.

Firstly, due to the distance from the center of Ghent to ArcelorMittal being more than double than that to Volvo Cars, the positioning of ArcelorMittal is said to be worse. Since more public transit is available in locations with a higher population density and Ghent being the most densely populated area of the analysed region, the public transit network is far less extensive close to ArcelorMittal than it is close to Volvo Cars. Only eight bus routes can be said to make-up the public transit network around ArcelorMittal [31] while there are a lot more bus routes close to Volvo Cars. The connection to the city center of Ghent is therefore much better for

Volvo Cars than it is for ArcelorMittal. The existing public transportation network has a higher marginal benefit for accessibility with the inclusion of a new route if this network has a low number of available routes. A new bus route in a small network means that unreachable people can become reachable and therefore this new route can have a high effectiveness. Adding a new route to a big network can at most reduce the travel time a little to certain locations. Since Volvo Cars is much better connected to the city center and therefore to a big transportation network, benefits of its private busses would be mostly felt in locations outside the city, regardless of their route in the center of Ghent. On the other hand, ArcelorMittal's private busses connect locations that are not easy accessible from their site because of the small transportation network. Therefore the lack of a good public transportation network for ArcelorMittal makes their private busses so more effective.

Secondly the aggregated location points of the employees of Volvo Cars and ArcelorMittal are visible in figures 4.3a and 4.3b, respectively. Most of the locations of Volvo Cars are located in and around the city center of Ghent and therefore have a good public transit available to reach the Dampoort from where a number of bus routes and Max Mobiel provide access to the site of Volvo Cars. Since the benefits of their private busses cannot be felt inside the city or in accessible locations as for reasons mentioned earlier, almost no private bus stops are made in the locations with a high number of employees that are shown in figure 4.3b. Therefore the private bus routes are forced to focus on connecting other locations with fewer employees. On the other hand, the private busses of ArcelorMittal can focus on connecting the locations with the most employees. This is due to the small transit network available around their site. One bus is concerned with connecting the city center of Ghent and the employees that reside there and the ones located in cities and villages to the south of Ghent, while the others can connect the employees in cities and village with a high number of employees in the rest of East Flanders. The goal of the private busses of Volvo Cars is therefore different from the goal of those from ArcelorMittal. Volvo Cars tries to connect the outskirt employees to the site with their busses while ArcelorMittal tries to connect as many employees as possible to the site.

4.5 Effect of the new railway line for employees

4.5.1 Effect of the new railway line for Texaco

In figure 4.10, the route of the new train is shown together with the extra areas that can reach Texaco within 60 minutes (in red) with the new train as part of the transportation network. The improvements lie to the north of Ghent (Zelzate) and little improvements to the east and west of Ghent.

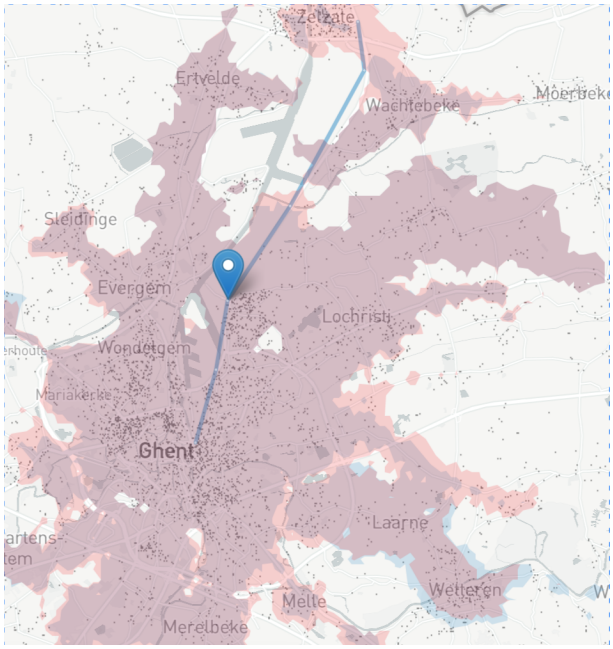


Figure 4.10: Visualised effect of the new train for Texaco

Transportation time reduction

The amount of extra employees that can reach Volvo Cars within 60 minutes with the new train as part of the transportation network is estimated at 226. This is a marginal increase of 6.21%.

The effect on the travel time to Texaco from the thirteen locations are visible in table 5.2. Three locations are altered by the presence of the new train with a time reduction of more than 30% for the connection from Dampoort since it has a train station right there. This gives an average travel time improvement of 4.95% for all thirteen locations.

Table 4.10: Travel time differences effect of the new train for Texaco (in min), location codes found in table 4.1

Location	With	Without	Difference	Time reduction (in %)	Only car
NNW8.1	-	-	-	0	-
NNE10.3	-	-	-	0	-
ENE8.0	-	-	-	0	-
ESE5.0	-	-	-	0	-
S11.8	-	-	-	0	-
NE7.1	-	-	-	0	-
NE2.7	-	-	-	0	-
SW3.1	-	-	-	0	-
SSE2.8	20	25	5	20	9
SSE8.4	38	44	6	13.64	16
SSW5.3	18	26	8	30.77	11
SE0.9	-	-	-	0	-
WNW6.1	-	-	-	0	-

Change of average number of transfers

Table 4.11 shows the effect of the new train on the number of transfers needed to reach Texaco within 60 minutes. An increase of 11.23% is present in the percentage of people able to reach Texaco within 60 minutes without transfers with the new train as part of the network. The estimated mean number of transfers with new train as an option is 0.3655. The estimated mean number of transfers without new train as an option is 0.5049. This is a reduction of 27.61% by the addition of the new train.

Table 4.11: Transfer differences effect of the new train for Texaco

	Number of transfers	0	1	2	3
With new train	**Number of people (CUSUM)**	2 643	3 698	3 799	3 849
	Number of people (distr)	2 643	1 055	101	50
	Percentage of people	68.67%	27.41%	2.62%	1.30%
Without new train	**Number of people (CUSUM)**	2 003	3 210	3 487	3 487
	Number of people (distr)	2 003	1 207	277	0
	Percentage of people	57.44%	34.61%	7.94%	0

4.5.2 Effect of the new railway line for Rostijne

In figure 4.11, the route of the new train is shown together with the extra areas that can reach Rostijne within 60 minutes (in red) with the new train as part of the transportation network. The improvements lie to the east of Ghent and at one of the new train stops at the site of Cargill (another important company that is part of the port of Ghent) located between the site of ArcelorMittal and the one of Volvo Cars.

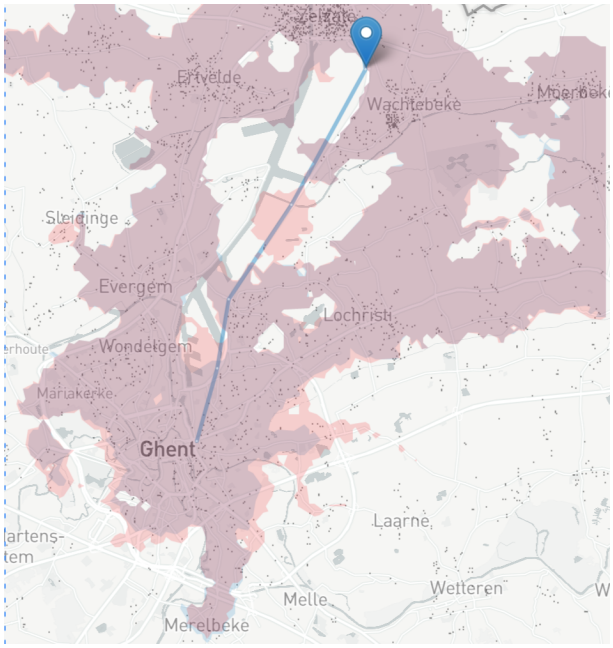


Figure 4.11: Visualised effect of the new train for Rostijne

Transportation time reduction

The amount of extra employees that can reach ArcelorMittal within 60 minutes with the new train as part of the transportation network is estimated at 56. This is a marginal increase of 2.64%.

The effect on the travel time to Rostijne from the fourteen locations are visible in table 5.4. Three locations are altered by the presence of the new train with a time reduction of almost 20% for the location at train station of Dampoort. This gives an average travel time improvement of 3.19% for all fourteen locations.

Table 4.12: Travel time differences effect of the new train for Rostijne (in min), location codes found in table 4.1

Location	With	Without	Difference	Time reduction (in %)	Only car
W9.9	-	-	-	0	-
W5.9	-	-	-	0	-
NW2.2	-	-	-	0	-
SSW3.1	-	-	-	0	-
ESE2.3	-	-	-	0	-
E7.1	-	-	-	0	-
ESE9.4	-	-	-	0	-
SE13.7	-	-	-	0	-
S9.7	-	-	-	0	-
SSW10.1	30	37	18.92	0	-
SSW15.1	42	52	19.23	0	-
SW12.9	-	-	-	0	-
WSW12.0	58	62	6.45	0	-
SSW21.9	-	-	-	0	-

Change of average number of transfers

Table 4.13 shows the effect of the new train on the number of transfers needed to reach Rostijne within 60 minutes. No significant changes are present in the number of transfers. The estimated mean number of transfers with the new train as an option is 0.1326. The estimated mean number of transfers without the new train as an option is 0.1314. This is no significant increase.

Table 4.13: Transfer differences effect of the new train for Rostijne

	Number of transfers	0	1	2	3
With new train	**Number of people (CUSUM)**	1 907	2 160	2 161	2 172
	Number of people (distr)	1 907	253	1	11
	Percentage of people	87.80%	11.65%	0.04%	0.51%
Without new train	**Number of people (CUSUM)**	1 856	2 124	2 124	2 124
	Number of people (distr)	1 856	279	0	0
	Percentage of people	87.38%	13.14%	0	0

4.5.3 Conclusion for the effectiveness of the new train

The effectiveness of the new train is analysed for existing employees (here) and potential new employees (in chapter 5). The effectiveness for the transportation of goods or other transportation motives than commuting are not analysed, although these also form important reasons for the project of this new train line. Therefore the total effectiveness of the new train is not measurable in the scope of this research.

In contrast to the conclusion about the effect of the other additions, where the employees of Volvo Cars and ArcelorMittal are examined separately, the impact of the new train is examined collectively for all employees.
Firstly, both companies have a marginal increase in the number of employees that can reach their sites within 60 minutes. Secondly, both companies are also better connected to the train station of Dampoort and by extension the city of Ghent. This is visible for the employees residing at Dampoort of both Texaco and Rostijne. This location has a travel time reduction of more than 30% to get to Volvo Cars and almost 20% to get to ArcelorMittal.
Thirdly, people residing close to train station across East Flanders have better access to the port of Ghent as can be seen by the travel time difference for the employees of Rostijne residing at Sleidinge. One of the private busses employed by ArcelorMittal already passes this location. Nevertheless, the employees residing there are better of taking the train to Ghent Dampoort and then take the new train.
Lastly almost 700 employees (mostly those of Volvo Cars) are estimated to be able to reach the work site without any transfers within 60 minutes.

To conclude, the effectiveness of the new train for the existing employees is high. It is able to form a much needed direct connection between the city of Ghent and its port. Not only are trains able to transport a lot more passengers than busses, they are also not hindered by traffic on the roads and can give a more stable travel time than a bus or even a car can.

4.6 Conclusion

The ferry is an important part of the transit network for employees residential west of the canal and in Zelzate (to the north of Ghent) of Texaco. Its usage is not limited to employees who use public transportation but extends to employees by car and people with other travel motives. It

operates as a bridge over the canal without the high cost of building one.

Max Mobiel offers a more flexible and comfortable alternative for employees and its effects are not measarable for employees of ArcelorMittal since a private bus does the same route. Employees of Volvo Cars on the other hand have no overlap between their private bus routes and Max Mobiel's route and therefore can experience a travel time reduction by using Max Mobiel (on top of the added flexibility and comfort). The flexibility comes from their reservation system for the employees.

The private busses form a most important part of the transportation network for employees. Its effect on the accessibility of ArcelorMittal is extraordinary and can form an interesting case study in itself that will be elaborated in chapter 6. The goal of the private busses of Volvo Cars is different from the goal of those from ArcelorMittal. Volvo Cars tries to connect the outskirt employees to the site with their busses while ArcelorMittal tries to connect as many employees as possible to the site. The yearly cost of the six bus routes of ArcelorMittal goes up to 1.5 million euros as was stated by the responsible person of ArcelorMittal. Since no yearly cost was stated by Volvo Cars and they have five bus routes, their yearly cost is estimated at 1.25 million euros.

The train line provides a fast and stable connection between the port of Ghent and Dampoort and Dampoort provides access to the different parts of Ghent. On top of that even better connection between the train stations across East Flanders to the port of Ghent will exist, making transfers less likely to be needed. Trains have other benefits in comparison with busses including the transportation of more passengers and not being hindered by traffic. The project is estimated to cost 30 million euros but its effect extend to transportation of goods and other transportation motives of people besides commuting.

Chapter 5

Improvements to the public transportation network to provide growth in workforce in the port of Ghent

In this chapter, the possibilities and their impact to extend the public transportation network in order to provide growth in workforce in the port of Ghent are examined. In this research only two extension, the new train route and a possible reroute for bus route 6. are found and the impact on the accessibility of Volvo Cars and ArcelorMittal are studied for both of these. These two routes can be seen in figure 5.1. The thought process of finding this extra bus route will be explained in this chapter too. The two new routes can be seen in figure 5.1. The routes do not follow the streets but the time between the stops is set as if they would. In order to properly describe the impact of the new routes on the accessibility of Volvo Cars and ArcelorMittal, a maximal transportation time of 60 minutes (as was used in chapter 4) can not be used. Since almost all statistical sectors with high unemployment rates in Ghent can reach the companies within 60 minutes, the improvements of a new route would only be visible in the travel time differences of the seven locations with high unemployment rates. This is, in itself, a good sign. But in favor of not blinding one metric to the effects of a new route, the maximal transportation time is set at 45 minutes.

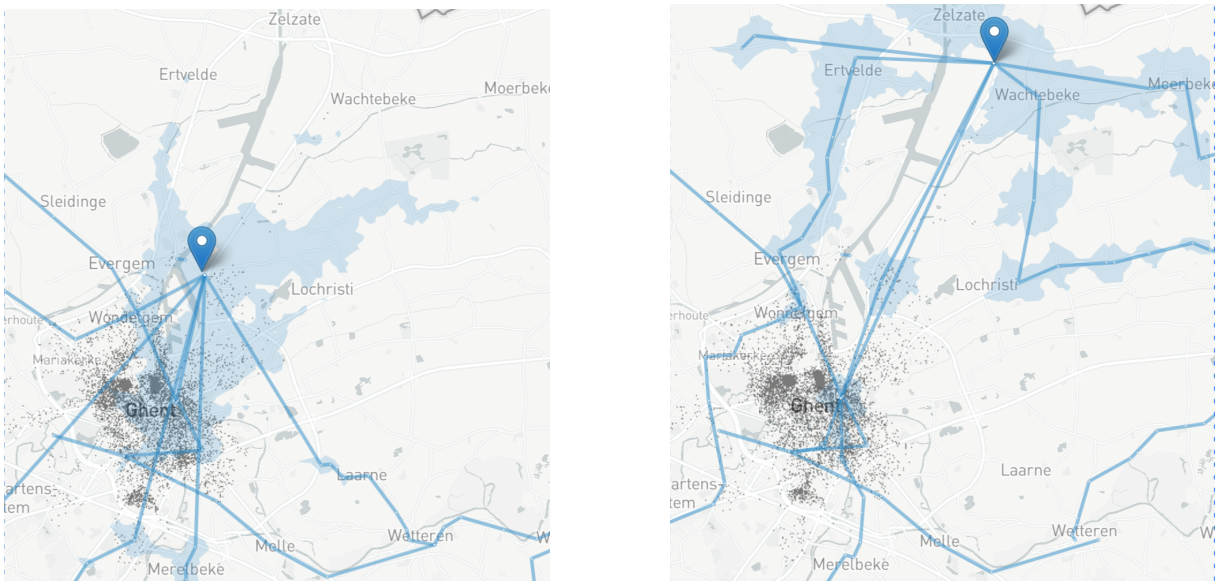
In this chapter, all figures are made with the help of Conveyal. For each analysis the parameters are set at a transportation time of maximal 45 minutes and a travel time percentile of 5%. The red colored areas on the figures represent the locations reachable (from the location marker) with the additional transportation method also at the disposal.

Figure 5.1: Visualised new bus and train route

5.1 Accessibility of port of Ghent for unemployed people

In figures 5.2a and 5.2b, the accessibility of Volvo Cars and ArcelorMittal within 45 minutes caused by the existing transportation network is visualised. The accessibility of ArcelorMittal is clearly worse from the city center of Ghent since no good connections exist between the two except for Max Mobiel's route and one private bus route of ArcelorMittal self. Providing a public better connection between these is one of the many reasons for the new train line. The amount of unemployed people that can reach Volvo Cars within 45 minutes is estimated at 7.183 with the existing transit network. The amount of unemployed people that can reach ArcelorMittal within 45 minutes is estimated at 2 368 with the existing transit network. The metrics of the following sections are dedicated to understand how large the effect of each of the two possible improvements actually is.

For clarity, the aggregation points of residential areas with a lot of unemployed people of Ghent (that were explained in chapter 3) are again shown here in figure 5.3. Tables 5.2, 5.4, 5.5, 5.7, 5.8 and **??** in this chapter will refer to these points with their codes in order to better understand the changes in travel time. The codes are shown in table 5.1. These codes represent the estimated direction and distance as the crow flies of each aggregated point from the city center of Ghent. For example the code *NNE1.2* of location 1 tells that point 1 lies 1.2 kilometers to the north-northeast of the city center of Ghent. The name of the statistical sector or municipality that the point is located in, are also shown. These names will be used for the interpretation of the measurements.



(a) Accessibility of Volvo Cars

(b) Accessibility of ArcelorMittal

Figure 5.2: Accessibility of locations within 45 minutes

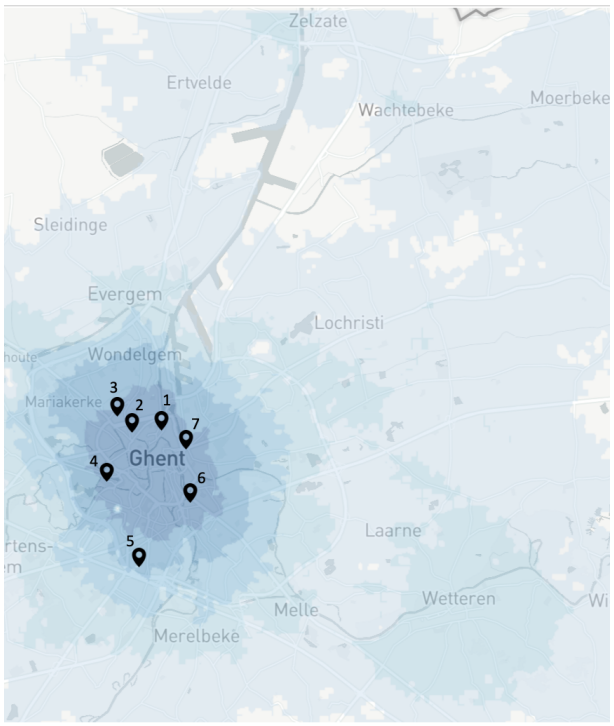


Figure 5.3: Aggregation points of unemployed people

Table 5.1: Number of aggregated points and their corresponding statistical sector and code

Number	Statistical sector	Code
1	Tolhuis	NNE1.2
2	Wondelgemstraat	NW1.4
3	Rustoord	NW2.3
4	Neermeersen	SW1.8
5	Nieuw-Gent	SSW3.4
6	Ledeberg centrum	SE2.1
7	Dampoort	ENE1.2

5.2 Effect of the new railway line

5.2.1 Effect of the new railway line on the accessibility of Volvo Cars

Figure 5.4 shows the extra areas that can reach Texaco within 45 minutes (in red) with the new train as part of the transportation network. The improvements lie to the north of Ghent (Zelzate). The extension of the area in and around Ghent is due to the new railway line providing

a faster connection from Dampoort to Volvo Cars.

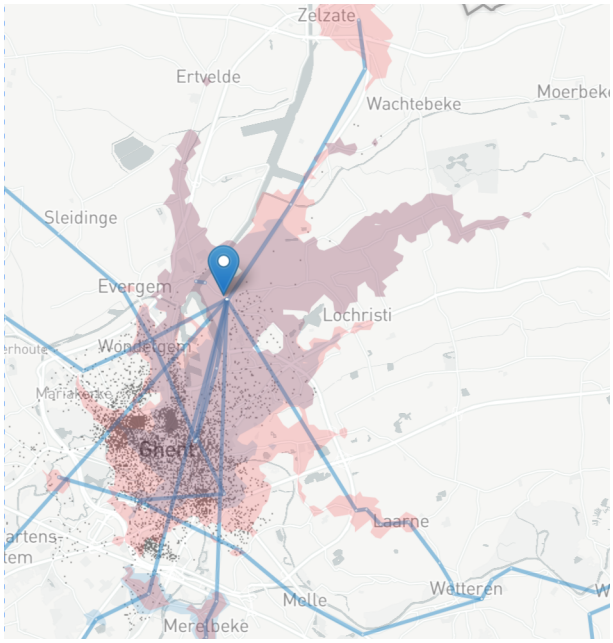


Figure 5.4: Visualised effect of the new railway line for Volvo Cars

Transportation time reduction

The amount of extra unemployed people that can reach Volvo Cars within 45 minutes is estimated at 2 884. Which is a marginal increase of 28.65%.

The effect on the travel time to Volvo Cars from the seven locations are visible in table 5.2. Five of the seven locations have a better travel time by the presence of the new train with a time reduction of more than 15% for three locations. This gives an average travel time improvement of 10.63% for all seven locations.

Table 5.2: Travel time differences effect of new railway line for Volvo Cars (in min), location codes found in table 5.1

Location	With	Without	Difference	Time reduction (in %)
NNE1.2	32	38	6	15.79
NW1.4	45	49	4	8.17
NW2.3	-	-	-	0
SW1.8	47	52	5	9.62
SSW3.4	-	-	-	0
SE2.1	35	42	7	16.67
ENE1.2	22	29	7	24.14

Change of average number of transfers

Table 5.3 shows the effect of the new railway line on the number of transfers needed to reach Volvo Cars within 45 minutes. 848 extra unemployed people are able to reach Volvo Cars within 45 minutes without transfers with the new train as part of the network. The estimated mean number of transfers with the new train as an option is 0.5634. The estimated mean number of transfers without the new train as an option is 0.4644. This is a increase of 21.32% by the addition of the new train. This seems like a drawback but this only due to more unemployed people being able to take a bus and then transfer to the new train and reach Volvo Cars within 45 minutes.

Table 5.3: Transfer differences effect of new train for Volvo Cars

	Number of transfers	0	1	2	3
With new train	**Number of people (CUSUM)**	4 917	9 656	9 955	10 067
	Number of people (distr)	4 917	4 739	299	112
	Percentage of people	48.84%	47.07%	2.97%	1.11%
Without new train	**Number of people (CUSUM)**	4 069	3 002	2	110
	Number of people (distr)	4 069	3 002	2	110
	Percentage of people	56.65%	41.79%	0.03%	1.53%

5.2.2 Effect of the new train on the accessibility of ArcelorMittal

Figure 5.5 shows the extra areas that can reach ArcelorMittal within 45 minutes (in red) with the new train as part of the transportation network. The improvements lie in the now accessible city center of Ghent and at one of the new train stops at the site of Cargill (another important company that is part of the port of Ghent) located between the site of ArcelorMittal and the one of Volvo Cars.

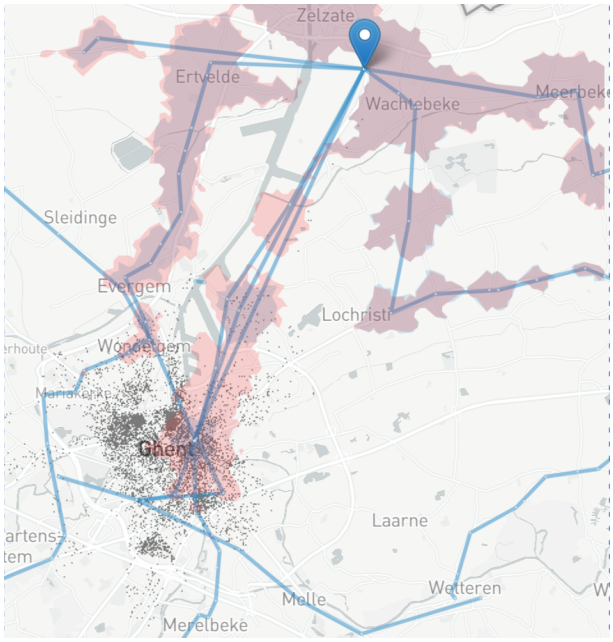


Figure 5.5: Visualised effect of the new train for ArcelorMittal

Transportation time reduction

The amount of extra unemployed people that can reach ArcelorMittal within 45 minutes is estimated at 1 825. Which is a marginal increase of 77.07%. This is mostly due to the unemployed people residing at Tolhuis now having a travel time of 45 minutes.

The effect on the travel time to ArcelorMittal from the seven locations are visible in table 5.4. Again five of the seven locations have improved travel times by the presence of the new train with time reduction of four locations being below 10% and one being above 15% (at train station Dampoort). This gives an average travel time improvement of 6.52% for all seven locations.

Table 5.4: Travel time differences effect of new train for ArcelorMittal (in min), location codes found in table 5.1

Location	With	Without	Difference	Time reduction (in %)
NNE1.2	45	49	4	8.17
NW1.4	52	57	5	8.77
NW2.3	53	56	3	5.36
SW1.8	56	60	4	7.14
SSW3.4	-	-	-	0
SE2.1	-	-	-	0
ENE1.2	31	37	6	16.67

Change of average number of transfers

No changes are found in the amount of transfers unemployed people have to take to get to ArcelorMittal.

5.2.3 Conclusion of the effect of the new railway for accessibility of the port of Ghent for unemployed people

The new railway line has a significant impact on the accessibility of the port of Ghent for the unemployed people as can be seen in the travel time differences it causes. Only Nieuw-Gent, in the south part of Ghent with a lot of unemployed people does not share this impact. The conclusion of this chapter goes further in the causes of the exclusion of this statistical sector. Although the median of difference in travel time for all locations is just 4 minutes, the railway would form a much needed stable connection to the port of Ghent. It is unaffected by traffic jams and does not make as many stops as a bus. Therefore the new train line (in normal circumstances) could provide more certainty in travel time.

5.3 Effect of the changed bus route

In this section the effect of the changed bus route is examined apart of the influence of the new railway line.

5.3.1 Effect of the changed bus route bus on the accessibility of Volvo Cars

Figure 5.6 does not show extra areas that have a better accessibility to Volvo Cars within 45 minutes with the changed bus route.

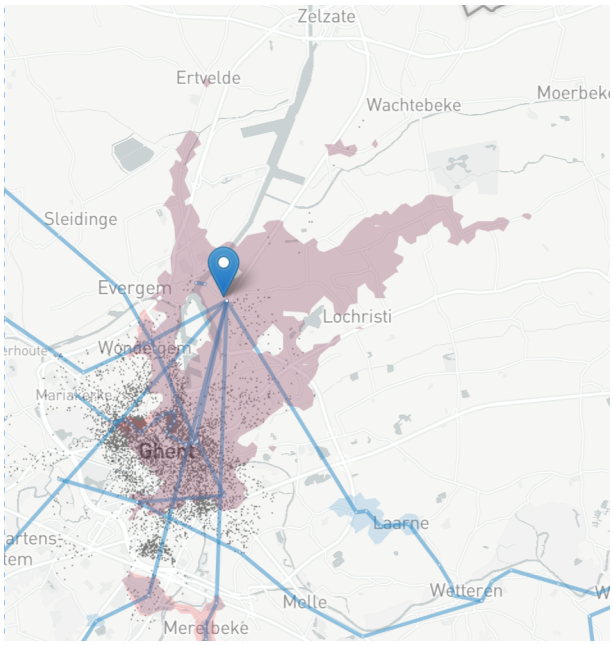


Figure 5.6: Visualised effect of the changed bus route for Volvo Cars

Transportation time reduction

The amount of extra unemployed people that can reach Volvo Cars within 45 minutes is estimated at 315. This is a marginal increase of 4.32%.

The effect on the travel time to ArcelorMittal from the seven locations are visible in table 5.4. The three locations that lie around the new bus route have improved travel times by its presence with time reductions above 10% for the two with the highest unemployment rate. This gives an average travel time improvement of 3.80% for all seven locations.

Table 5.5: Travel time differences effect of the changed bus route for Volvo Cars (in min), location codes found in table 5.1

Location	With	Without	Difference	Time reduction (in %)
NNE1.2	34	38	4	10.53
NW1.4	44	49	5	10.20
NW2.3	48	51	3	5.88
SW1.8	-	-	-	0
SSW3.4	-	-	-	0
SE2.1	-	-	-	0
ENE1.2	-	-	-	0

Change of average number of transfers

Table 5.6 shows the effect of the changed bus route on the number of transfers needed to reach Volvo Cars within 45 minutes. No noticeable amount of extra unemployed people are able to reach Volvo Cars within 45 minutes without transfers. The estimated mean number of transfers with the new bus as an option is 0.5457. The estimated mean number of transfers without the new bus as an option is 0.4644. This is a increase of 17.51% by the addition of changed bus route. This seems like a drawback but this only due to more unemployed people being able to reach Volvo Cars within 45 minutes if they are allowed to transfer.

Table 5.6: Transfer differences effect of the change bus route for Volvo Cars

	Number of transfers	0	1	2	3
With new bus	**Number of people (CUSUM)**	4 104	7 400	7 630	7 796
	Number of people (distr)	4 104	3 296	230	166
	Percentage of people	52.64%	42.28%	2.95%	2.13%
Without new bus	**Number of people (CUSUM)**	4 069	3 002	2	110
	Number of people (distr)	4 069	3 002	2	110
	Percentage of people	56.65%	41.79%	0.03%	1.53%

5.3.2 Effect of the new bus on the accessibility of ArcelorMittal

Figure 5.7 does not show extra areas that have a better accessibility to ArcelorMittal within 45 minutes with the changed bus route.

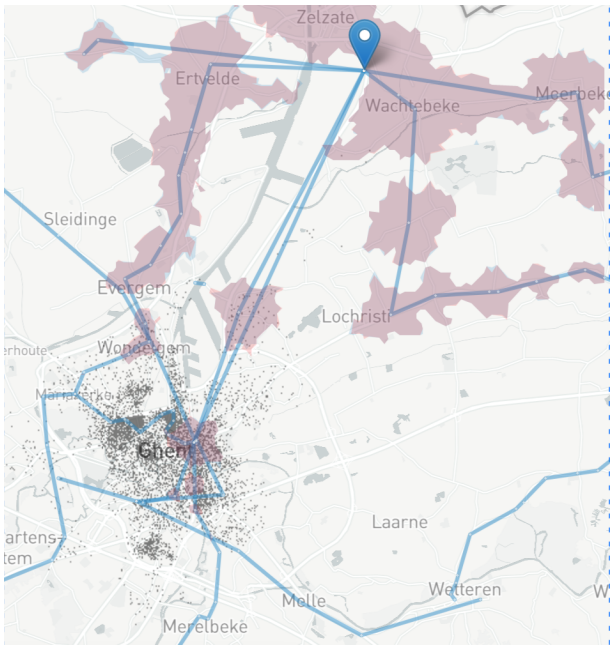


Figure 5.7: Visualised effect of the changed bus route for ArcelorMittal

Transportation time reduction

No change in the amount of unemployed people that can reach ArcelorMittal within 45 minutes is noticed.

There are time reductions above 5% for the two with the highest unemployment rate on the route of the bus. This gives an average travel time improvement of 1.63% for all seven locations.

Table 5.7: Travel time differences effect of the changed bus route for ArcelorMittal (in min), location codes found in table 5.1

Location	With	Without	Difference	Time reduction (in %)
NNE1.2	46	49	3	6.12
NW1.4	54	57	3	5.26
NW2.3	-	-	-	0
SW1.8	-	-	-	0
SSW3.4	-	-	-	0
SE2.1	-	-	-	0
ENE1.2	-	-	-	0

Change of average number of transfers

No changes are found in the amount of transfers unemployed people have to take to get to ArcelorMittal.

5.3.3 Conclusion of the effect of the changed bus route for accessibility of the port of Ghent for unemployed people

When only examining the figures, the effect of the changed bus route could easily said to be redundant. Which is not the case when looking at the travel time differences that it provides for unemployed people living in the statistical sectors that the route now passes through. Two locations even have time reductions of more than 10% in their respective travel time to Volvo Cars.

The reason for the lower effect on travel time for ArcelorMittal than for Volvo Cars is because of one of the private bus routes of ArcelorMittal. Potential employees in Tolhuis and Wondelgemstraat can take a public bus to Wondelgem (located in the northwest corner of Ghent), a submunicipality of Ghent, and then transfer to the private bus that passes through there. With the changed bus route passing through Tolhuis and Wondelgemstraat, it now becomes the best option to take this bus to Dampoort and to take there another private bus of ArcelorMittal. Both of these options rely on the private busses of its adjoining company. On the other hand, if the new train line is already present, one would assume the effect of the suggested changed route to be more effective for ArcelorMittal since a faster and more reliable connection is present between Dampoort and ArcelorMittal, making the option with the transfer in Wondelgem less interesting still. This hypothesis is tested in the section below.

5.4 Effect of the changed bus route with the new train as part of the transit network

In this section the effect of the changed bus route is examined when the new railway becomes part of the transit network.

5.4.1 Effect of the changed bus route on the accessibility of Volvo Cars with the new train as part of the transit network

In this case, figure 5.8 shows the improvement provided by the changed bus route as the red area in the northwest corner of the city center of Ghent.

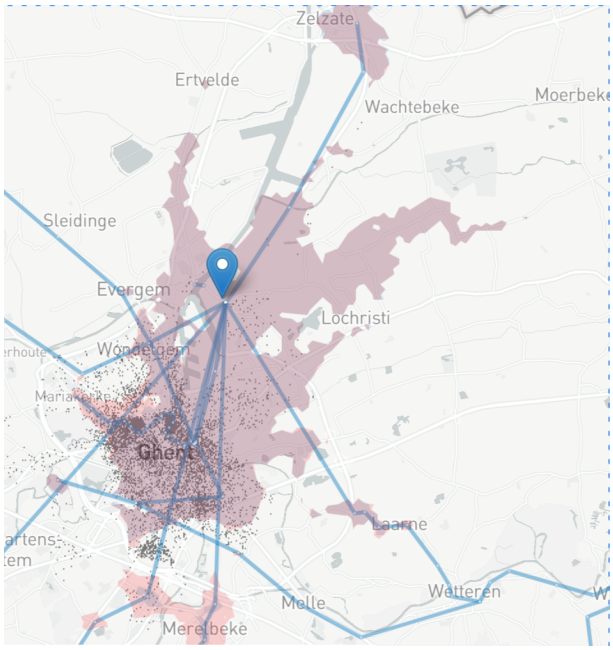


Figure 5.8: Visualised effect of the changed bus route for Volvo Cars with the new train as part of the transit network

Transportation time reduction

The amount of extra unemployed people that can reach Volvo Cars within 45 minutes is estimated at 208 with the train as part of the transit network. This is a marginal increase of 1.84%.

The effect on the travel time to Volvo Cars from the seven locations are visible in table 5.8. The three locations that lie around the changed bus route have improved travel times by its presence with time reductions up to 20% for the two with the highest unemployment rate. This gives an average travel time improvement of 5.55% for all seven locations.

Table 5.8: Travel time differences effect of the changed bus route for Volvo Cars with the new train as part of the transit network (in min), location codes found in table 5.1

Location	With	Without	Difference	Time reduction (in %)
NNE1.2	28	32	4	12.5
NW1.4	36	45	9	20
NW2.3	44	47	3	6.38
SW1.8	-	-	-	0
SSW3.4	-	-	-	0
SE2.1	-	-	-	0
ENE1.2	-	-	-	0

5.4.2 Effect of the changed bus route on the accessibility of ArcelorMittal with the new train as part of the transit network

Again no extra areas have a better accessibility to ArcelorMittal within 45 minutes with the changed bus route, as can be seen in figure 5.9.

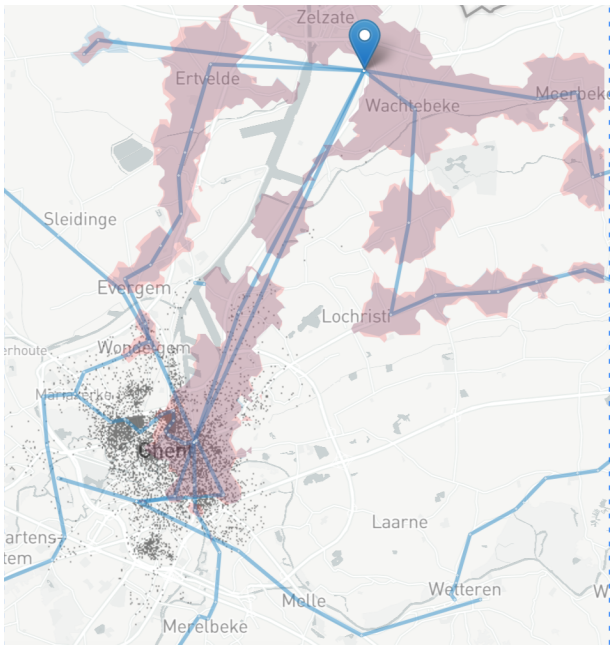


Figure 5.9: Visualised effect of the changed bus route for ArcelorMittal with the new train as part of the transit network

Transportation time reduction

The amount of extra unemployed people that can reach ArcelorMittal within 45 minutes is estimated at 465 with the train as part of the transit network. This is a marginal increase of 9.12%.

The effect on the travel time to ArcelorMittal from the seven locations are visible in table 5.9. The two locations that lie around the changed bus route have improved travel times by its presence with time reductions above 10% for both. This gives an average travel time improvement of 3.47% for all seven locations.

Table 5.9: Travel time differences effect of the changed bus route for ArcelorMittal with the new train as part of the transit network (in min), location codes found in table 5.1

Location	With	Without	Difference	Time reduction (in %)
NNE1.2	40	45	5	11.11
NW1.4	46	53	7	13.21
NW2.3	-	-	-	0
SW1.8	-	-	-	0
SSW3.4	-	-	-	0
SE2.1	-	-	-	0
ENE1.2	-	-	-	0

5.4.3 Conclusion of the effect of the changed bus route for accessibility of the port of Ghent for unemployed people with the new railway as part of the transit network

The effect of the changed bus route on the travel time becomes, as hypothesised, bigger for the connection to ArcelorMittal from Tolhuis and Wondelgemstraat. Apparently the same can be said for the connection between Volvo Cars and Wondelgemstraat. An analogical reasoning, as stated in the above conclusion, can be made for this connection. In this case, the option is taking a bus to Mariakerke (located more in the west-northwest edge of Ghent), also a submunicipality of Ghent and then taking a private bus deployed by Volvo Cars. This connection to Volvo Cars is just as for the connections to ArcelorMittal, further out shined by the presence of the connection to Dampoort and the new railway line there.

5.5 Conclusion

Firstly, the effect of the train is spread across the different locations giving almost all locations improvements in accessibility to the port of Ghent. The effect of the changed bus route is (only) felt in the places it passes through, in particular the statistical sectors Tolhuis and Wondelgemstraat. The train line provides a fast and stable connection between the port of Ghent and Dampoort and Dampoort provides access to the different parts of Ghent (and thus the different locations with high unemployment rates). On the other hand does the changed bus route only provide a better connection for Tolhuis and Wondelgemstraat (and by extension Rustoord) to Dampoort. The effect of the changed bus route is thus smaller than the effect of the new train but this changed bus route is also an almost costless improvement. The changed bus route uses existing bus stops and only changes the course of one bus line while the cost for the new railway is estimated at 30 million euros [22]. The effect of the railway is not limited to commuting but extends to the transportation of goods and other transportation motives.
Secondly, the effect of the changed bus route becomes more prominent with the presence of the new train. This is due to the locations Tolhuis and Wondelgemstraat (and by extension Rustoord) with high unemployment rates becoming less dependent on the private busses of the companies examined.

Chapter 6

Discussion and conclusion

6.1 Discussion

Combining the results of chapter 4 and 5, the patterns that emerge when examining all (possible) additions to the transportation network and their effect on the targeted districts. This is done in order to better comprehend the components of a good public transit network, the accessibility of a company and the needs that certain groups of people require from the transit network for commuting.

6.1.1 Additions to the public transit network

Ferry This forms an important part of the transportation network for employees of the Port of Ghent residential at the west side of the canal due to the lack of a bridge in its vicinity. Ideally, the ferry is replaced by a bridge to secure a permanent connection between the two banks of the canal. This has a two main advantages that follow from extensively examining the transportation network of Ghent.

Firstly, a bus route can form a direct (and faster) connection with the port of Ghent via the west side by eliminating one transfer. A bus would make this route also a better option for people using the public transit that do not work for Volvo Cars but for another company located in the port of Ghent. This route with the ferry requires a lot of walking since the stop of the ferry is located almost 1 kilometer from the next bus stop.

Secondly, the bridge would also improve the transportation time for a person residential at the west side of the canal that commutes by car to the port of Ghent. The improved transportation

time by car would extend to the whole western part of Ghent. This makes the route passing Dampoort and its congested roundabout even less appealing.

Max Mobiel An independent company that offers commuting employees an alternative to the existing public transit. Volvo Cars and ArcelorMittal employ Max Mobiel to facilitate commuting since both sites are sometimes difficult to reach with public transportation alone at the hour the employee's shift begins. Max Mobiel provides their service only when employees need it (or in other words when the public transit is not available) which means their benefit to the transportation network comes from their flexibility in working hours. Max Mobiel exploits the bounded working hours of public transit.

Private busses The private busses are designed to make the company's site easier accessible for people that do not want or are able to use a car. These locations are found further away from the site, not in cities and not on main connection roads to the site. A significant difference in effectiveness is found between the private busses of ArcelorMittal and Volvo Cars. Two important parameters are found to declare the effectiveness of the private busses deployed by a company. These are explained extensively in chapter 4 (in the conclusion for the effect of private busses). the accessibility of the site with public transit and the residential location of its employees.

The first parameter is the accessibility of the site by public transit. The closer a company is located to the center of a city, the better it is(/should be) accessible with public transit and the less benefit there is from introducing a new (private) bus route. The positioning of the site in the public transit network can therefore give a company an initial idea in the need for private busses.

The second parameter are the residential locations of the company's employees. If the employees reside outside the city, some will have public transit available to the closest city where the site of the company may not be located close to. Providing a private bus route that forms a direct connection for commuting to the site can therefore be very effective. If, however, the employees reside in and around the center of the city, most will have decent public transit available. The company should therefore focus the private busses on providing fast connections between the city and their site. This should not be limited to one connection from the closest accessible point at the edge of the city but should extend to multiple connections from accessible points all around the edge of the city.

New train The effectiveness of the new train for the existing employees is high. It is able to form a much needed direct connection between the city of Ghent and its port. Not only are trains able to transport a lot more passengers faster than busses can, they are also not hindered by traffic on the roads and can give a more stable travel time than a bus or even a car can since they do not rely on the existing road network.

Changed bus route The changed bus route improves the transportation time of people living in the vicinity of the stops. It becomes even more effective when the new train is part of the public transit network. It shows first hand how difficult changes in the public transit network inside a city are without changes of the road network. Tolhuis and Wondelgemstraat are located on 1.4 and 2.3 kilometers from the site of Volvo Cars but still have transportation times around 40 minutes at best. This illustrates that some problems can not be solved completely without structural changes of the transportation network.

6.1.2 Districts accessibility: Nieuw-Gent

Nieuw-Gent is the only statistical sector with a high unemployment rate that is unaffected by any changes in the public transit network. Two public transit routes have stops there and provide a connection with the big train station of Ghent, Gent-Sint-Pieters, and the public transit hub, Gent Zuid. But it is located in the most southern part of Ghent and will therefore always experience longer travel times to reach the port in the north. The only possibility for better accessibility to the port could be via a direct connection to Dampoort or immediately to the port.

6.1.3 Public transportation planning

Lastly, a flowchart is set out to aid policymakers and managers in identifying how to improve the accessibility of a location, as is shown in figure 6.1. In order to better understand this flowchart and the reasoning behind it, it is also explained here. If employees residing at a certain location have difficulties to access the site of the company by transit, first check the mobility from that location to the site. The mobility can be measured as the quotient of the aerial distance and the travel time by car.
If the mobility is low, then the road network causes the low accessibility in the first place. Changes in the road network are needed or committing to alternative travel options (such as

train or bike) to improve accessibility.

If the mobility is high, the the transit network causes the low accessibility. Then subsequent checks are needed in order to determine the needed improvement. Firstly, check if transit is even available at the location. Public transit always flows through important transit hubs. Transit hubs each have a high number of different bus routes stops at its location. Ghent has three so called transit hubs: Gent-Sint-Pieters, Gent Zuid and Dampoort. If the employees' residential location has no connection with a transit hub, then making one should be prioritised. This should be done for general accessibility and not only for job accessibility. Secondly, check if transit provides a connection to the site of the company. If this is not the case, a connection should be made between the transit hub (that is accessible) and the site. Thirdly, check if transit provides a direct connection to the site. Direct connection can mean two things: a connection without the need of transfer or stricter, a connection without passing a transit hub first. This should be installed if not the case. If however, all of these things exist in the transit network, the speed of all connection should be questioned.

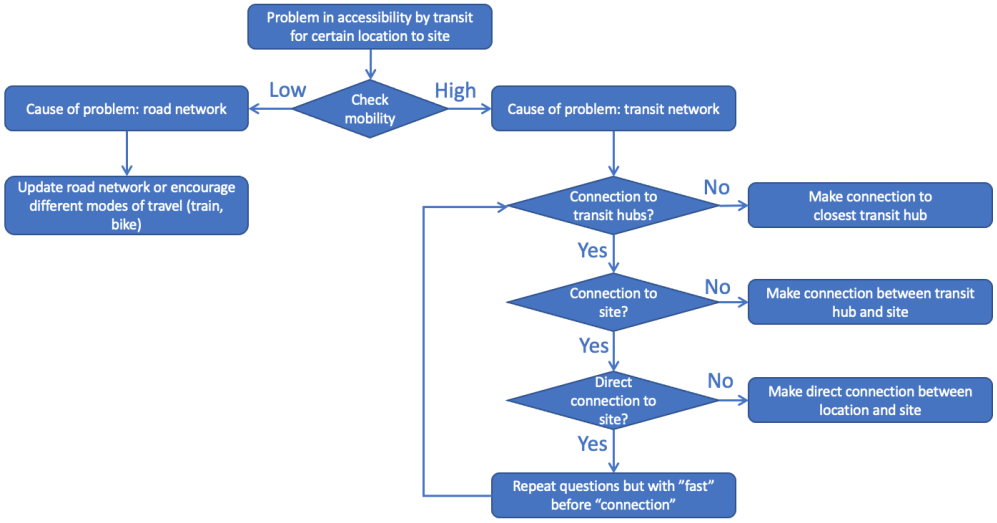


Figure 6.1: Flowchart to find improvement

6.2 Conclusion

Up to this point, studies defined job accessibility from the perspective of a person. On top of that is the differentiation between jobs left out in order to get to the metrics of job accessibility. This makes it still hard for policymakers to address the causes of the failures in the transportation network in the right way. The objectives of this research focused on job accessibility for different

groups from the perspective of the company. Different research-backed accessibility metrics are determined to examine the accessibility of the areas with a high number of available jobs with public transit in order to provide more insight into the failures of the transportation network for commuting. Different scenarios are created to examine the effect caused by changes in the transportation network. The analysed region in this research is Ghent. In Ghent, there are four statistical sectors that emerge as employment attraction poles; two in the port of Ghent, one in the city center and one south of the city center. This last one is the statistical sector that encompasses the academic hospital of Ghent (UZ Gent). The two in the port of Ghent are Texaco and Rostijne and they encompass the corporations Volvo Cars and ArcelorMittal, respectively. These companies have the largest number of employees in the port of Ghent but have few bus routes passing there [30] [31]. Companies even deploy private busses to improve accessibility. Therefore this research analyses the effect of the additions of the transportation network for the employees in the port of Ghent. The focus is extended to unemployed job seekers, since these companies have difficulties filling in all job openings. Patterns emerged from the analysis phase of this research and the insight it brought into good public transportation networks, company accessibility, and the needs of certain groups of people is elaborated. The culmination of this research is the flowchart that can aid policy makers and managers in identifying possible improvements in accessibility of a location.

This research gives an in-depth analysis of commuting to the port of Ghent and can form a guide for improvements in that area.
The simulations of this research are imposed to some limitations. It does not include traffic and traffic jams or the timing of the trip. The commuting data is also a bit outdated since it is from 2011 and does not have information about every person exactly.
The flowchart is very broad and offers therefore no assurance for applicability in every situation. It forms more of a basis for guidelines than actual guidelines.

6.3 Future work

An important thing to keep from this research is the need to look differently at job accessibility. Researching job accessibility from the perspective of the job can give additional insight in transportation patterns in commuting across a region. New researches that still want to hold on to the traditional perspective of the people can at least introduce differentiation between types

of jobs. This is necessary to improve the description of reality with the indexes.

An important subject is also formed by examining the residential areas of employees of Volvo Cars and ArcelorMittal and the companies' private bus routes. A lot of employees of ArcelorMittal reside around the private bus routes, outside the city of Ghent. While the employees of Volvo Cars can be found more inside the city, away from the private bus routes. Why is there a difference between these two? Why do employees of Volvo Cars not also reside around the private bus routes? Is there a even a causal effect of the private bus routes on the residence location?

Appendix A

Extra figures

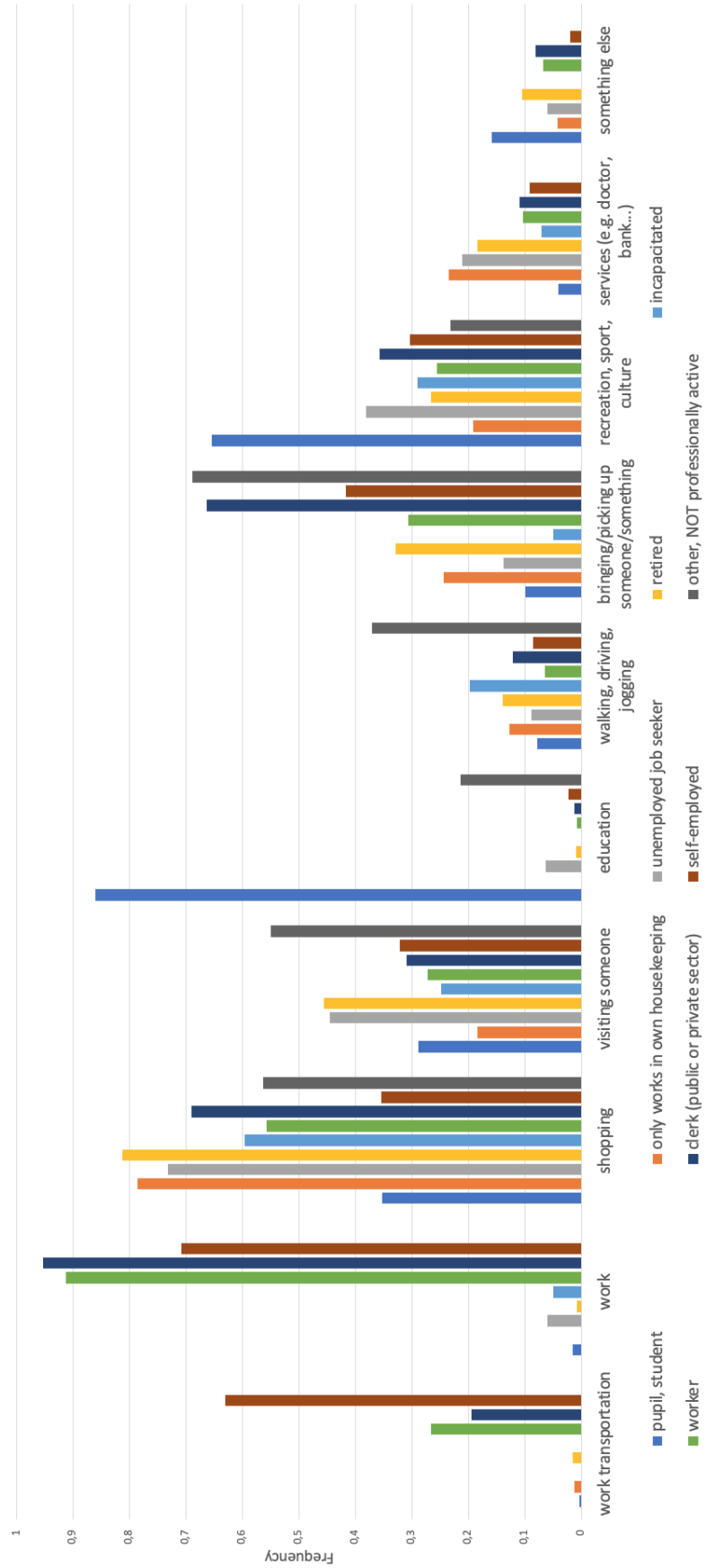


Figure A.1: Frequency of Average Number of Displacements per Day per Status and Motive

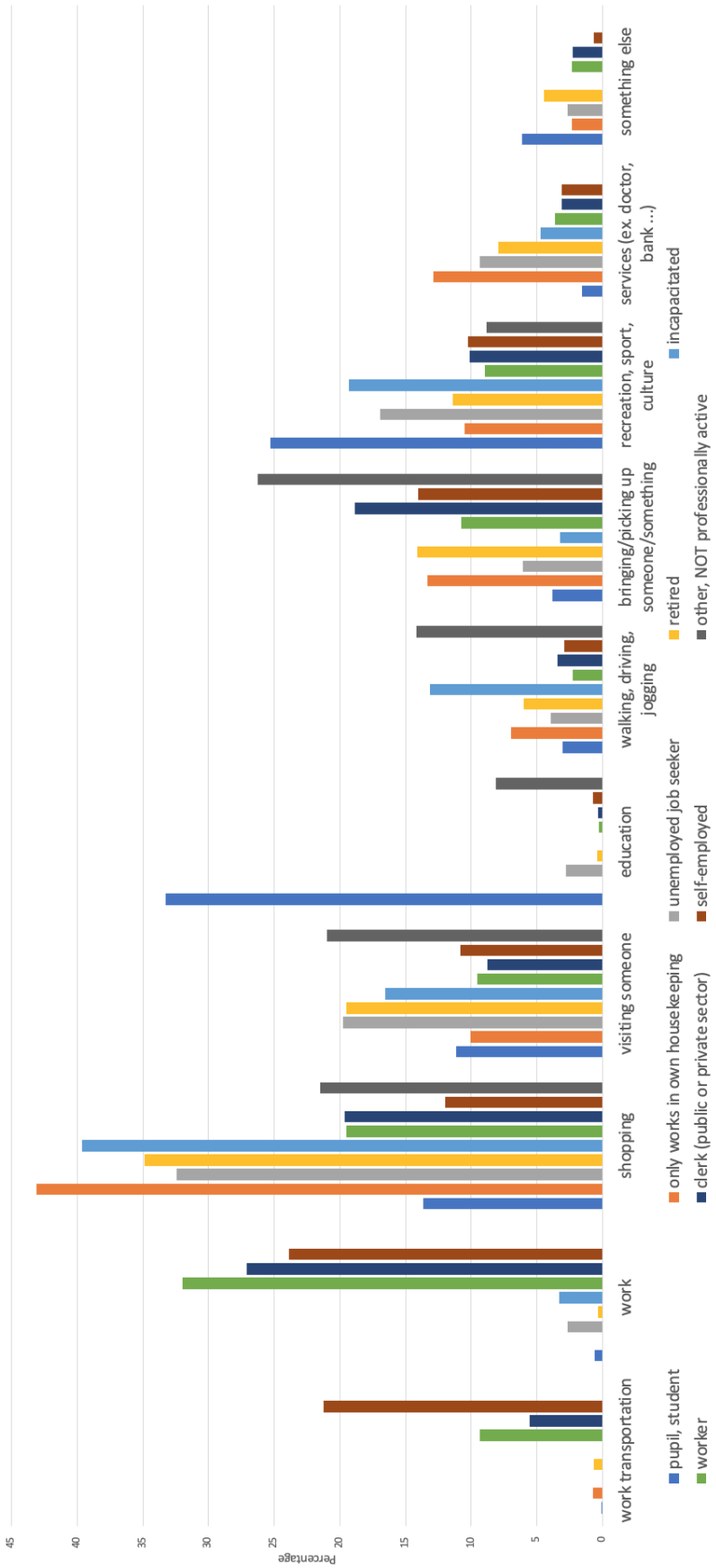


Figure A.2: Percentage per Status of Average Number of Displacements per Day per Motive

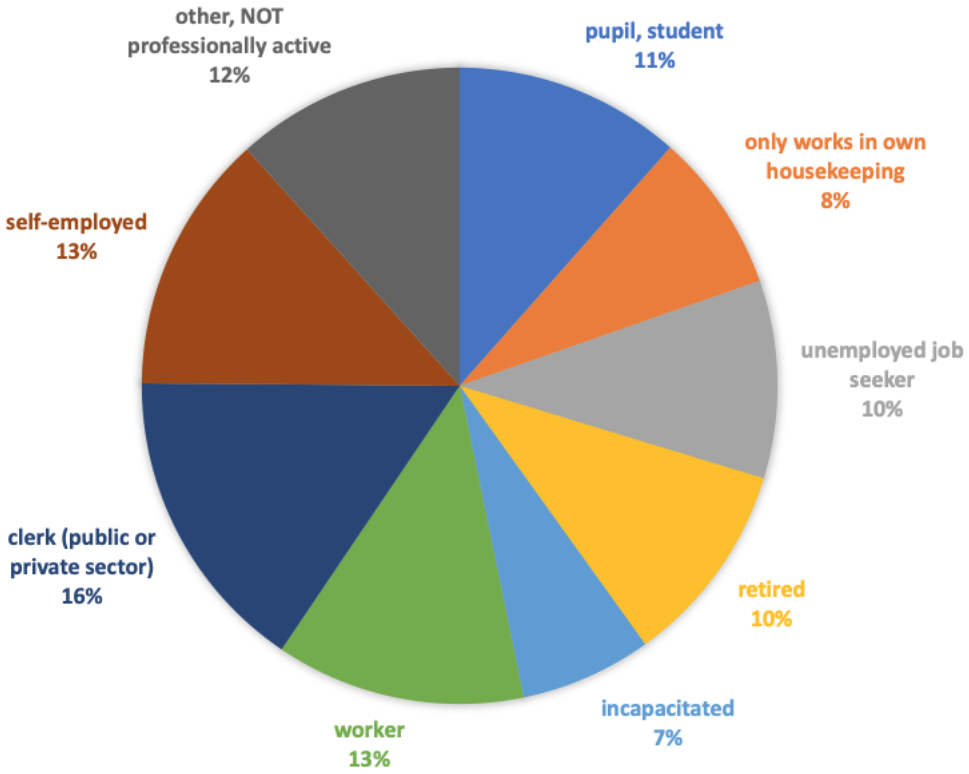


Figure A.3: Distribution of Transportation per Status

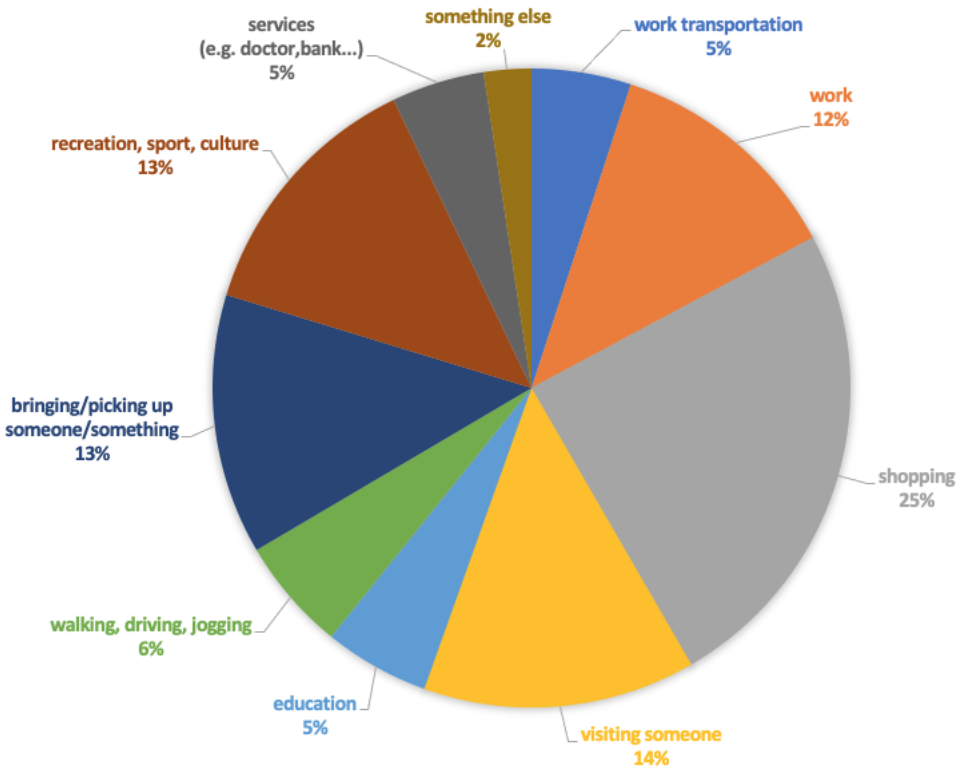


Figure A.4: Distribution of Transportation Motives

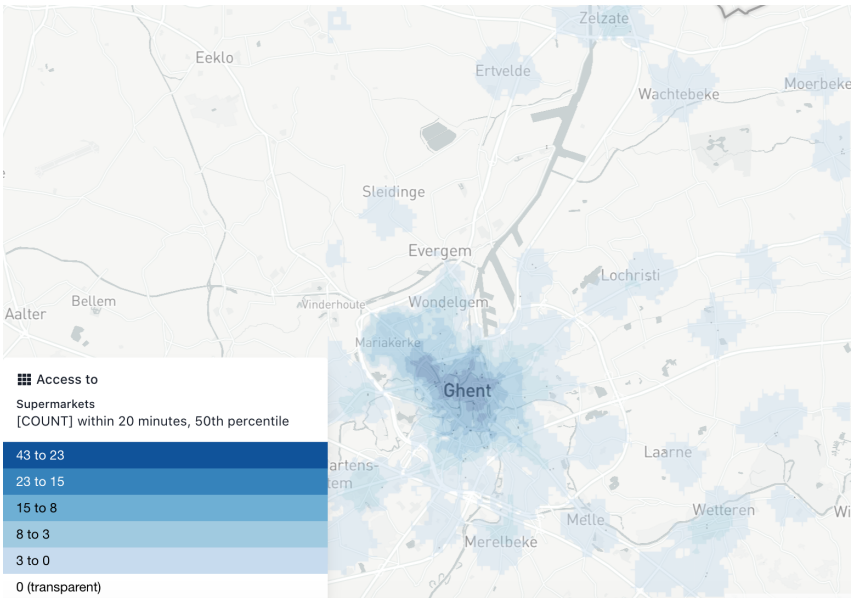


Figure A.5: Accessibility of Supermarkets

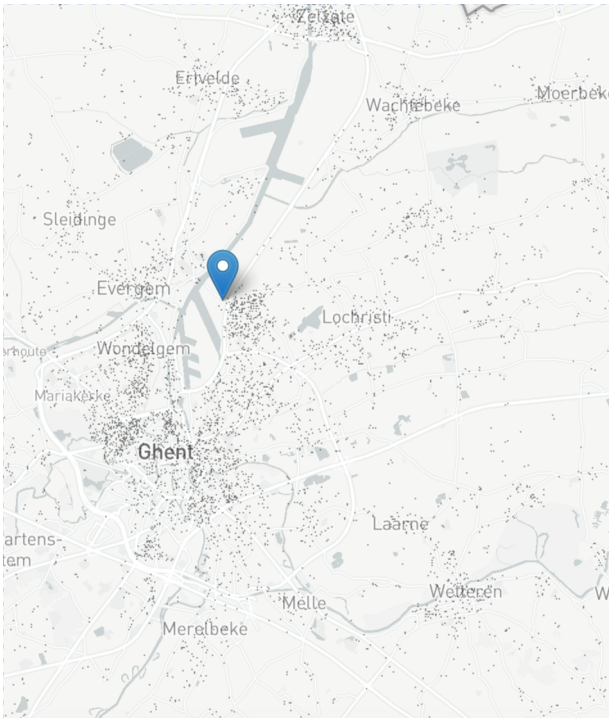


Figure A.6: Estimated locations of each employee of Texaco in the analysed region

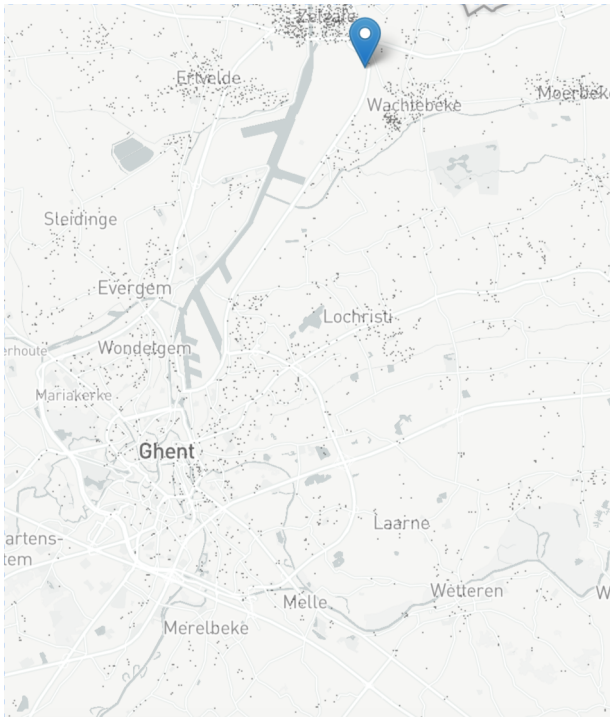


Figure A.7: Estimated locations of each employee of Rostijne in the analysed region

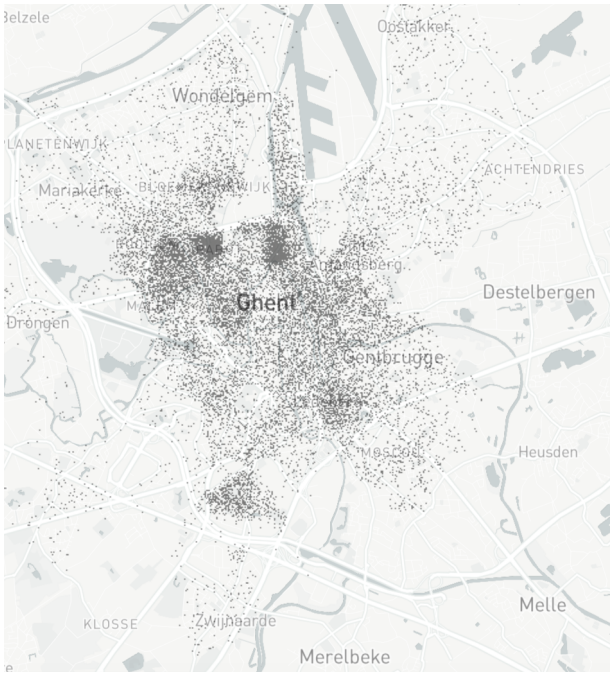


Figure A.8: Estimated locations of each unemployed person in Ghent

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FACULTY OF ENGINEERING AND ARCHITECTURE

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