Next stop: Social Exclusion?

The Effects of Public Transport Frequency Reduction On the Accessibility Of Jobs in Rotterdam, the Netherlands

Master's Thesis

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BY
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I. Abbreviations and terminology

Abbreviations

Abbreviation	Definition
BVOV	*Governmental aid for PT* *Beschikbaahriedsvergoeding Openbaar vervoer*
CBS	Dutch Statistics *Centraal Bureau voor de Statistiek*
CPB	Netherlands Bureau for Economic Policy Analysis *Centraal Planbureau*
PBL	Netherlands Environmental Assessment Agency *Planbureau voor de Leefomgeving*
MRDH	Metropolitan Region Rotterdam the Hague *Metropoolregio Rotterdam Den Haag*
PC4	Postal codes (4-digit)
PT	PT
PTO(s)	PT operator(s)
SES	Socio-economic status
SSI	Social severity index

Terminology

Area	Spatial area, smaller than a neighborhood. Based on PC4.
Concessioner	A governmental institution which is the client for granting contracts to PTOs for running PT services within their sovereign area(s).
District	Designated administrative division of the city, recognized by the municipality. *Stadsdeel*
Neighborhood	Geographically localized community. The combination of neighborhoods makes a district. (If a neighborhood is mentioned, the district wherein the neighborhood is situated will be named between brackets.) *Wijk*
PT Service level	Referring to the frequency of the PT services

I. Samenvatting

Door de uitbraak van het coronavirus in Nederland in maart 2020 en de introductie van de 'anderhalvemetersamenleving' zijn vervoersbedrijven en concessiehouders gedwongen om het openbaar vervoer af te schalen. Het gebruik van het openbaar vervoer in Nederland daalde in maart 2020 met circa 87%. In Maart 2021 maken circa 45% tot 55% van het aantal reizigers, die we in 2019 zagen, gebruik van het ov. In het verleden is al bewezen dat het reduceren van het openbaar-vervoersaanbod enorme gevolgen kan hebben voor hen die afhankelijk zijn van OV voor hun dagelijkse verplaatsingen. Naast dat het voornamelijk lager opgeleiden, jongeren en ZZP'ers zijn die door de coronacrisis hun baan zijn verloren, is dit ook een significante groep die, zeker in grootstedelijk gebied, vaak niet de beschikking heeft over een auto. Zo beschikt 16% van de Rotterdammers (c.q. 94.000) niet over een fiets. Tezamen met de mogelijk economisch ongunstige tijden in het verschiet, is het van belang dat juist hen met een lagere socio-economische status (SES) een goede en volwaardige toegang hebben tot arbeidsplaatsen met het OV. Dit ter voorkoming van om zo mogelijke werkloosheid, onnodig hoge verplaatsingskosten en uiteindelijk mogelijke vervoersarmoede en uitsluiting uit de samenleving.

Vervoersarmoede houd summier in dat men niet meer in staat is om plaatsen, goederen of diensten te bereiken die men graag wilt bereiken en die bereikt dienen worden om volwaardig mee te doen in de samenleving. In het licht van de reducties in het aanbod van openbaar vervoer in de stad, tezamen met de potentiële verdere bezuiniging op de nu geldende beschikbaarheidsvergoeding OV (BVOV) die vanuit de overheid wordt afgegeven aan de concessiehouders, ontstaat de noodzaak om te onderzoeken wat de sociaal-maatschappelijke gevolgen zijn van: (1) De bezuinigingen op het openbaar vervoer die nu al, in crisistijd en vrij abrupt, zijn ingevoerd sinds maart 2020; (2) Een eventuele verdere afschaling van het openbaar vervoer in de stad. Deze twee situaties zijn onderzocht met Rotterdam als *focus city*. Simulaties van de afschaling van OV en de daaropvolgende verslechtering van banenbereikbaarheid zijn uitgevoerd met het verkeersanalysemodel van de metropoolregio Rotterdam Den Haag (MRDH) gesimuleerd.

Uit het eerste scenario is gebleken dat in de huidige situatie, waarbij het OV-aanbod met circa 10% is gedaald, de bereikbaarheid van arbeidsplaatsen mee-daalt. Tussen de 2,5% voor gunstig gelegen plaatsen tot meer dan 10% in de randen van de stad. Voor het tweede scenario, waarbij is uitgegaan van een krimp van 30% van het OV-aanbod vergeleken met 2019, zien we een afname van tussen de 10% en 20% van het aantal bereikbare banen. Met een reistijd van 45 minuten, spreken we hier over een afname van circa 50.000 bereikbare arbeidsplaatsen.

Door ook in kaart te brengen welke wijken gevoelig zijn voor het fenomeen vervoersarmoede, zijn de uitkomsten uit de simulaties interpreteerbaar als een zogenoemde *Social Severity Index*. Deze index kijkt dan

niet alleen naar de afname van bereikbare banen in een wijk, maar ook naar de gevoeligheid voor vervoersarmoede in de betreffende wijk. Hiermee is in kaart gebracht waar op dit moment - en in de mogelijke toekomst - de 'zwakke plekken' van Rotterdam liggen. Hieruit is gebleken dat Rotterdam-Zuid nog steeds een tamelijk hoge gevoeligheid heeft voor vervoersarmoede. Zeker vergeleken met de rest van de stad. Waarschijnlijk mede veroorzaakt, doordat in Zuid er vaker een overstap nodig is om bijvoorbeeld het centrum (waar veel werkgelegenheid is) of Noord te bereiken. Deze aansluitingen kunnen kort en goed zijn, maar de afname van het OV-aanbod en slechte afstemming tussen bijvoorbeeld bus en metro kunnen lange wachttijden ontstaan die niet bevorderlijk zijn voor de gebruiksvriendelijkheid van het OV.

Het is goed dat er in het recente verleden aandacht is geweest voor dit onderwerp vanuit overheidsinstanties. Echter is er door de coronacrisis extra noodzaak bijgekomen om dit probleem aan te pakken. Aangezien er vanuit vervoersbedrijven vaak ook een groot financieel drijfveer is om dáár te rijden waar veel reizigers zijn, is het voor overheidsinstanties extra van belang om bij het wijzigen van vervoersplan in de stad extra kritisch te zijn en extra focus te leggen op de sociaal-maatschappelijke aspecten van het openbaar vervoer. Het opheffen of reduceren van lijn X kan natuurlijk heel andere sociaal-maatschappelijke gevolgen hebben dan het opheffen/reduceren van lijn Y. Ook het belang van sterke en hoogfrequente lijnen kan, op bepaalde plaatsen, ook een grote rol spelen in het tegengaan van vervoersarmoede. Dit onderzoek dient dan ook voornamelijk als voorzetje voor overheidsinstanties om zich meer bewust te worden van de combinatie van ov-verbindingen aanbod en sociaal-maatschappelijke waarde voor inwoners van de '*catchment areas*' van deze ov-verbindingen. Zeker daar waar men beperkte andere mobiliteitsmogelijkheden heeft.

II. Summary

After the outbreak of the coronavirus in the Netherlands in March 2020, public transport organizations and concessioners were force to reduce their services, as in March 2020 the decrease in passenger demand for public transport shrunk by 87% nationwide.

As a result of the pandemic, many lost their job. In the total number of individuals who have lost their job during the pandemic, an over-representation of socially vulnerable groups is visible.

Especially in urban environments car dependability is lower in the Netherlands. However, For the possession of a bicycle, ethnic differences are also visible. These individuals are reliant on public transport for their mobility. Along with the economic forecast for the near future being worrisome, it is even more important to protect those who have already suffered the most during the pandemic. The potential decrease of their travel options because of a decrease in public transport, along with the pessimistic economic forecast and increasing unemployment because of the pandemic, calls for concerns, as this can lead to an increase in transport poverty which eventually can lead to social exclusion.

Transport poverty is about not being able to access goods and services which are needed to actively participate within society. With service cuts being executed and a potential decrease in government funding, the need for research to evaluate the possible sociological impact of public transport reduction is high. Therefore, this research will, based on simulations, create insight in two scenarios: (1): The effects of PT frequency reductions which have already been executed during the pandemic and (2): The effects of further reduction of PT frequencies in case government funding will be further reduced. These simulations have been executed to access the effects of public transport reduction on the accessibility of jobs in the city of Rotterdam. The main question this research is: 'How can the impact of the PT frequency reductions on transport poverty be minimized for groups without alternative transport in the city of Rotterdam?' Based on the first scenario where PT frequencies were reduced by 10%, the accessibility of jobs decreased between 2,5% to 10% In the second scenario, the job accessibility of the city decreased on average by 20%. For 45 minutes of travel time, about 50.000 jobs became inaccessible.

By showing these simulations, this research strive to grow awareness of the different effects that the reduction of PT services can have throughout the city. As several socio-economic characteristics differ per neighborhood the dependability on PT does accordingly. This research gives insight on the consequences of PT reduction and the severity of reductions in places where the potential for transport poverty is high. The research is meant as insight for governmental institutions to focus more on the social characteristics of their neighborhoods and to make the connection with the social function of public transport. Especially in neighborhoods were other social factors are unfavorable, proper public transport can make a difference in mitigating transport poverty and eventually social exclusion.

Content

1. Introduction

Throughout a year dominated by the fight against Covid-19 and safeguarding of national health, the impact the pandemic has had on sociological matters is worrisome. The novel coronavirus magnified social inequality issues on various topics related to e.g. education (Bol, 2020), ethnicity (Pilkington, 2020), gender (Fare et al., 2020), health care (bambra et al., 2020), and income (Darvas, 2020). Spatial mobility tends to be no exception. The first wave in March 2020 resulted in an 87% drop in daily check-ins in public transport (PT) in the Netherlands (Translink, 2021). Resulting in Dutch Railways (NS) temporarily canceling all Intercity services nationwide (NS,2020). The public transport operator (PTO) in Rotterdam, RET, reduced its services by around 50% to 60% (RET, 2020).

Despite the working-from-home mantra opposed by the government, not everyone was able to work from home. Taking a look at who was still traveling by PT during the first wave, unequal distribution of income levels was visible. Trips made by PT dropped between 70% for the highest income groups, while only a 30% to 40% drop was registered for the lowest income groups (Tirachini, 2020).

To prevent PTOs in the Netherlands from collapsing, the Dutch government stepped in to cover over 90% of the operational costs for all PTOs to run business-as-usual. (van Veldhoven-Van der meer, 2021). However, a year into the pandemic, the government started to request service reductions in exchange for extra aid (van Ammelrooy, 2021*)*. Therefore, PTOs and concessioners are currently evaluating various cost-cutting measures e.g. reduction of staff, network restructuring, and reduced operating hours and frequencies (OVPro, 2021).

Next to spatial mobility, job losses were also unequally distributed during the first wave. Despite the actions of the Dutch government, the level of unemployment in the Netherlands rose 26% during the first wave, compared to 2019 (CBS, 2021b). Though, most affected by the mass lay-offs during this wave, were individuals with temporal or flexible contracts. These types of contracts are particularly prevalent amongst youth, lower educated individuals, and individuals with a non-western migration background (SCP, 2021). Consequently, the combined effect of the reduction of PT services along with increased job loss among marginalized groups endanger the spatial mobility of those relying on PT.

1.1 Social and Scientific Relevance

Just before the outbreak of the virus, Environmental Assessment Agency (PBL) (2019) published research on spatial mobility and the risks of transport poverty in the Netherlands. Briefly explained, transport poverty is about not being able to get where one wants or needs to be. The phenomenon covers the lack of availability, accessibility, and affordability of travel options (Pawlik, 2020). Research by PBL (2019) showed that the Dutch public transport system is prone to transport poverty. Particularly, the urban poor and lower educated have been identified as having the highest risk potential for transport poverty (Martens et al., 2012). Especially as these groups often lack other mobility options. Those who already had a historically marginalized social position in our pre-Covid-19 society, are also less likely to own a car (CPB, 2009; Brown, 2017). Moreover, 46% of households in the lowest income quintile do not have any driver's license or do not have access to a motorized vehicle (CBS, 2018).

Bastiaanssen et al., (2021) have been able to connect the negative effects of poor job accessibility by PT on worsening employment outcomes for PT users. Poor PT can result in the urban poor getting stuck in a vicious cycle, as the lack of private transport and insufficient PT are two of the five biggest predictive factors for social exclusion[1] (EC, 2012).

Now that the economic forecast for the upcoming years is, according to CPB (2020), worrisome, the potential for an increase of social exclusion in the Netherlands is high. Especially when considering that 1 of every 75 households in the Netherlands is not able to financially survive for at least six months in case of job loss. Even when including social securities (Hofs, 2020). Economic downturns, such as the previous financial crisis of 2008 have shown that increased job loss, generally results in negative economic and social consequences for those who have lost their job. (SEU, 2003). The level of poverty and social exclusion increased within the European Union as a result of that financial crisis (EC, 2021).

1.2 Research Objective

The link between financial position and spatial mobility has been reviewed by Meert (2003), who found that the financially poorest within society tend to have the lowest level of spatial mobility. Furthermore, research by Cascajo et al., (2018) already identifies the negative effects of ticket price increases on lower-income groups. 'The poor' generally pay more for PT than higher-income groups (Bondemark et al., 2020). On top of that, remaining PT services are to be reduced to cut expenses on PT by governmental bodies. the current risks, for those relying on PT for their spatial mobility, lays in reduced accessibility of desired destinations, such as jobs. Therefore, with this research, the objective is to examine the consequences of PT frequency reductions, and what the effects are of those reductions on transport poverty potential.

[1] Social exclusion refers to the inability to participate in activities, available to the majority of people within society (*Levitas et al., 2007*)

Transport poverty is noted by Martens (2017) not to be a regional problem perse, but even more a challenge for the (poorer) outskirts of sub-urban and metropolitan areas (Martens & Bastiaanssen, 2019). Kampert et al., (2018) have already indicated the transport poverty potential on the micro-level for Heerlen and Utrecht in the Netherland. They showed that transport poverty in some neighborhoods in these cities is something to worry about.

Concerning the contemporary health crisis and pessimistic economic outlook, a critical review on transport equity[2] is needed to protect the weakest in society from falling behind even more. Given the historic research on similar topics in the city of Rotterdam (Bastiaanssen, 2012; Bruinse, 2016; van der Bijl & van der Steenhoven, 2019), and the current rise in unemployment, the Rotterdam area is chosen as an area of interest for this research. Before the pandemic, Rotterdam, the second-largest city in the Netherlands, home to 651.269 individuals, already had relatively high unemployment rates (CBS, 2017a, Onderzoek010, 2021a), making Rotterdam an interesting case to review the potential effects of the reduction of PT frequencies on transport poverty and social exclusion. Therefore, I propose the following main research question**:**

How can the impact of the PT frequency reductions on transport poverty be minimized for groups without alternative transport in the city of Rotterdam?

The main research question is rather complex and has to be split up to be able to answer the question as a whole. answering a few sub-questions will be used as a guide towards understanding and answering the main research question. These sub-questions include descriptive, explanatory, and policy-related questions.

1. What is the impact of the covid-19 pandemic on the PT service level in Rotterdam since March 2020?
2. What areas of Rotterdam are, according to their socio-economic characteristics, prone to transport poverty?
3. Why are PT frequencies affecting transport poverty in the city?
4. What are suitable strategies to minimize transport poverty potential in Rotterdam?

1.3 Scope

This research focuses on current PT frequency reductions in Rotterdam, the Netherlands. Reductions that have been executed since January 2021 and the potential further reduction of PT services have been forecasted by PT and concessioners. The goal is to evaluate the effects of changes in PT services frequencies on the accessibility of jobs of PT users. The pre-Covid PT frequencies as were run in 2016, will be used as the basis for comparison for two scenarios: (1) The first scenario focuses on PT service frequencies as currently known

[2] The equal distribution of mobility options (BRON)

during the pandemic. (2) The second scenario will evaluate what will happen in case of possible future cuts in government funding for PT. More detailed scenario descriptions can be found under 3.4 Scenario and Simulation Description. The scenarios will evaluate what has happened to the accessibility of jobs when using PT and whether there are differences between areas within Rotterdam.

2. Theory outline

This chapter gives an overview of the theoretical framework used for this study. The theories used in this framework will guide the research process and will help to draw conclusions ones data gathering has been completed.

2.1 Social Exclusion

The contemporary term '*social exclusion*' refers to the physical and financial inaccessibility of goods and services, which withholds affected individuals from active citizenship and full participation within society (Lucas, 2012). For instance, physically disabled individuals might have a good PT network in their vicinity, but when there are no accessibility options for the disabled available to physically enter PT (e.g. elevators), they cannot make use of it at all (Meert et al., 2003). Social exclusion is a complex and broad definition, which not only evaluates personal circumstances, but also institutional availability of resources. Adopting the terminology as used by Levitas et al., (2007), the definition of social exclusion can be better conceptualized for this research: "…the lack,or denial of resources, rights, goods and services, and the inability to participate in the normal relationships and activities, available to the majority of people in a society, whether in economic, social, cultural or political arenas." (Levitas et al., 2007: 9)

The concept of social exclusion overarches the sole terms of 'poverty' and 'low income', but is closely related to them (SEU, 2003). The problem of social exclusion is, according to Rajé (2003) related to the inaccessibility of services, which increases the perceptual feeling of becoming excluded from society. According to Lucas (2012), the definition by Levitas et al., (2007) helps to explain three important aspects of social exclusion: Firstly, it recognizes that the problem of social exclusion is multi-dimensional (e.g. cultural, economic, political, social, spatial) which covers the individual level, but also institutional level, and is carved in the societal structure. Secondly, the disadvantage is seen as a direct opposite of the normal life. And lastly, the definition identifies the dynamic nature of the concept; The concept can change over time and space. An important dimension of social exclusion is the lack of mobility resources (Wixey et al., 2003).

2.1.1 Transport-related social exclusion

Research focused on transport-related social exclusion gained more attention by the end of the 20th century (SEU, 2003, Lucas, 2012). Nowadays, much research has already been done on the inter-relation between transport-related social disadvantage and societal problems as unemployment (Kawabata, 2003), health inequalities (Sanchez et al., 2003), educational attainment (Hernandez, 2018), and underdevelopment of neighborhoods (Wang & Woo, 2017).

PT is recognized as one of those factors that help to prevent individuals from getting socially excluded by offering the freedom to travel without the help of others. Defunding PT and reducing the level of service and frequency of the network will impact this freedom. Fewer opportunities to travel can be translated to the individual being more restricted in their spatial mobility. When PT will become less interesting options to reach desired destinations, individuals with access to alternative forms of mobility (private transport, electric bicycle) are likely to shift away from PT. However, not all individuals can make this switch. Some do not have access to a car nor bicycles (Bastiaanssen, 2012) and have to adjust their life to the reduced PT frequencies offered. The frequency reduction of PT can form a new barrier for the accessibility of goods and services such as jobs, medical treatment, education, but also socially oriented matters, such as visiting friends and family (Martens & Bastiaanssen, 2015). Leading to an increased risk of social exclusion for those who rely on PT. As this thesis will focus on the accessibility of jobs in the first place, it is hypothesized (H_1) that: 'PT frequency reductions will lead to more unequal accessibility of jobs because of unequal mobility opportunities'.

reduced access to PT will lead to more social exclusion for those who rely on PT. This hypothesis seems rather straightforward. However, it is yet not known whether a percentual decrease in PT frequency levels generates a linear decrease in accessible jobs. To assess whether an individual will be prone to social exclusion, it has been first to be determined what spatial characteristics can lead the way to transport-related social exclusion, or transport poverty.

2.1.2 Social exclusion and the spatial dimension

As the answering of this research desires to not only evaluate (potential) transport-related problems based on personal (in)capabilities, but also needs an investigation into the effects of the decrease of opportunities caused by the individual's surrounding environment, one must first understand the two main dimensions of travel in general: 'Time' and 'space'. These two dimensions are decisive in the determination of the range wherein movement is possible for the individual and its corresponding opportunities within that range. To broaden the view on the aspects of transport-related social exclusion, a slight diversion from the sociological approach on spatial mobility is needed to better understand the surrounding environment's influence on the travel options of individuals. The sociological approach where the individual and his various forms of capital are the center focus point is needed, but next to that it is crucial to analyze the effects of socio-geographical demographics surrounding the individual. In fact, two types of questions that are most important in this way of thinking are the sociological question of: "Who gets what why?" (Lenski, 1966), and the socio-geographical one: "Who gets what where?" (Smith, 1977).

In sociology, the term mobility is foremostly used to define the level of movement in social classes. Social classes can be identified by e.g. level of socio-economic status (SES), educational attainment, or cultural group. At first glance, this might differ from the 'mobility' in spatial terms, whereas the emphasis is laid on the movement of people from A to B. However, when discussing spatial and social mobility, one can identify several similarities in the clarification of the terms. According to Kaufmann (2004) both forms of mobility:

- are related to structural change and social transformation
- are concerned with preconditions and consequences of movement
- Emphasizes the importance of space (social vs. geographic) and time (temporal effects on social position and structure vs. speed of displacement of goods, information, and people)
- comprises different spheres of activities, resources, and institutional arrangements.

Kaufmann (2004) hereby shows that both forms of mobility are needed to understand what possibilities can withhold individuals from getting from A to B. Social exclusion is not just a matter of a lack of (socio-economic) competencies by the individual, but also by possibilities made available by the individuals' surrounding environment.

2.2 Transport Poverty

The term 'transport poverty' is created to identify those who are not able to participate within societal activities that are available to the majority of people in a society, because of their inability to reach these activities. They are unable to function within society in a way they would prefer, (Martens et al., 2011). transport poverty can be seen as a significant obstacle for the fulfillment of basic needs and is therefore recognized as a determining factor for social exclusion. (Pawlik, 2020). "Transport poverty encompasses various deprivations relating to transport access and affordability" (Mattioli et al., 2017). Transport poverty is not just about not having an adequate bus service in the vicinity, but can also relate to the high cost of car ownership putting a hole one family expenses (Churchill, 2019), or about personal assets (e.g. income, physical and mental health) being sufficient to facilitate the use of PT, and whether PT can facilitate in the needs and desires of the individual.

According to Lucas (2012), transport poverty can be a consequence of a mixture of two disadvantage factors that lead the way towards social exclusion: Personal disadvantage factors (social disadvantage), as well as institutional-focused disadvantage factors (transport disadvantage), are, according to Lucas (Idem.) affecting one's spatial mobility. Figure 1 shows the relationship between social disadvantage, transport disadvantage, and social exclusion. Her illustration promptly addresses the inter-relation between the various personal and institutional factors that contribute to transport poverty. The diagram illustrates that transport poverty is a sum of the personal circumstances of the individual, along with the institutional circumstances affecting the individual. Negative results in both personal and institutional factors eventually can lead to inaccessibility of essential goods and services, which distances the individual from society. Ultimately, the individual faces social exclusion.

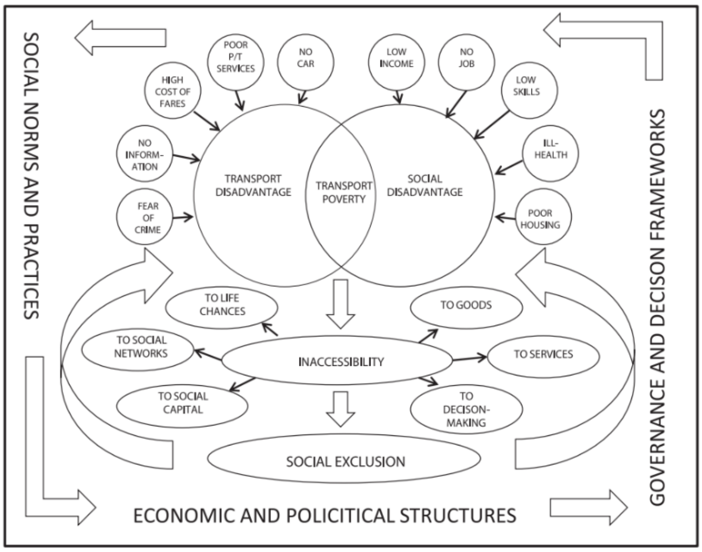

Figure 1. The relationship between Transport Disadvantage, Social Disadvantage and Social Exclusion (Lucas 2012: 3)

On the flip side, not every individual is equally prone to transport poverty. Jeekel (2011) already sheds his light on the trend of services and shops moving into peripheral areas, increasing car accessibility. Against this greater car accessibility usually stand a worsened accessibility for those without a car. In latter situation, having a car can be a preventive good for becoming transport poor. However, former research on transport poverty tells us that solely having a car is not a reliable barrier for the prevention of transport poverty, but only lowers the risk of becoming transport poor (PBL, 2019).

2.2.1 Transport poverty in the Netherlands

Generally, the Netherlands is known for its proper cycling infrastructure and relatively low car dependability within urban areas. The bicycle is therefore seen as an explanation for the modest levels of transport poverty within urban regions in the country (Martens, 2017). The bicycle also helped to decrease car dependability (potential transport disadvantage) within the Netherlands. However, Bike ownership differences between different social groups and socio-economic classes are visible. Van Der Kloof et al., (2014) showed that individuals having a migration background tend to cycle less than non-migrants, but instead have a higher usage of PT and do walk more.

2.2.2 Transport poverty mitigation in place in Rotterdam

Focusing on the illustration of Lucas (2012) in Figure 1, some of the social- and transport disadvantage factors are being prevented by the action of either the municipality of Rotterdam or the PT concessioner MRDH. On the side of transport disadvantage, the city of Rotterdam itself has already created a safety net to prevent high costs of fares. To keep the cost of travel low for individuals with low income, the city of Rotterdam offers discounts and free travel for the elderly (>65 years of age) and reduced tariffs to leisurely destinations, and a PT travel budget for low-income households. The *Rotterdampas* is an example of these initiatives. (Waalraven & van der Kooij, 2018). Next to that public safety and security are constantly monitored by the concessioner, MRDH (MRDH, 2016). However, there is a positive relationship between the level of education and travel distance to work. So higher education often translates into a longer travel time to work (Zijlstra, 2014). If the reward gets higher, individuals tend to accept a longer travel time to work (Muth, 1969). Also, De Koning et al., (2017) found that most lower-educated workers in and around Rotterdam geographically live closer to their work, than higher educated citizens of the city.

3. Method & Case Description

In this chapter, the execution of the research will be described. However, firstly the sources of the researched parameters of transport poverty will be explained and how to transport poverty potential will be measured in this study, using the 'Social Severity Index'. Thereafter follows some information regarding the MRDH traffic model used for the simulations. Lastly follows a brief description regarding the simulated scenarios.

3.1 Scoping Transport Poverty

In Figure 1 of Lucas (2012), it has been made visible that the term transport poverty is connected to various transport disadvantage and social disadvantage-related frameworks. Making the subject a complex subject of research. Therefore, and in the light of time and data constraints, this research will primarily focus on certain frameworks that have a link with transport poverty, and are in the eyes of the research, most prone to contribute to an increase in transport poverty, during the contemporary PT challenges. Also, this study is more scoped towards the impact of reduction of PT frequencies citywide; Leaving car-related-transport-poverty indicators out of scope. Indicators linked to both areas of transport poverty: social disadvantage and transport disadvantage that have haven been included in this research have been made visible in Figure 3.

According to recent documentation from concessioners such as the Zuid-Holland province (Provincie Zuid-Holland, 2021), MRDH (MRDH, 2021), and Utrecht province (Provincie Utrecht, 2021), it is very likely that PTOs must significantly reduce frequencies to avoid financial challenges. Therefore, poor PT service, in the form of poorer frequencies, is the main area of interest on the subject of transport disadvantage, as PT service level is currently being reduced as a result of the pandemic, while lower educated benefit from greater job opportunities not too far away from home.

On the side of social disadvantage, poor housing and ill-health are out of scope for this research, as testing these factors requires personal contact with individuals, which is undesirable during the pandemic. The remaining frameworks of social disadvantage are of interest for this research. Next to the lower than average income and often more peripheral and suburban location within cities, the inhabitants of low SES areas tend to be at the highest risk of transport poverty within urban areas Martens & Bastiaanssen, 2019). The level of public housing in an area can also act as an indicator for lower-income within the neighborhood as there are strict rules on who can apply for such housing. E.g. an income check is mandatory to apply for public housing. According to the latter indicators, the following hypothesis (H_2) is proposed: 'PT frequency reduction will increase transport poverty potential in Rotterdam.'

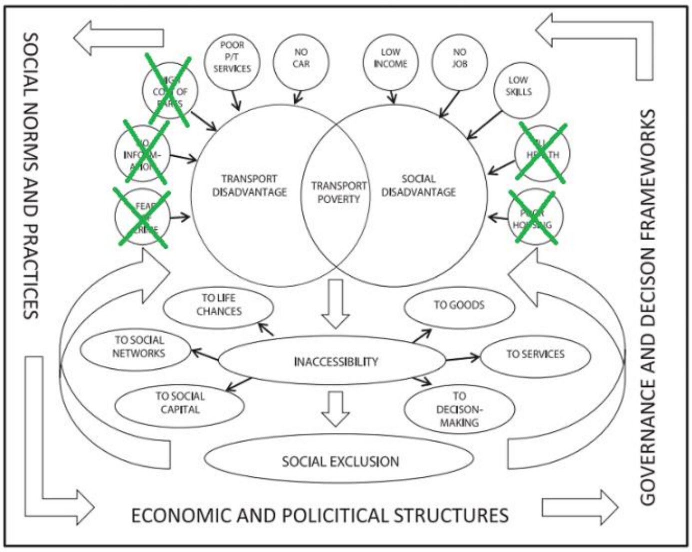

Figure 3. researched parameters of transport disadvantage and social disadvantage for his research. Based on the scheme of Lucas (2012: 3)

3.2 Social Disadvantage Characteristics of Neighborhoods in Rotterdam

Based on socio-economic characteristics the neighborhoods of Rotterdam have been analyzed. to understand what neighborhoods house individuals who are more prone to transport poverty than others.

As there currently is no data available to the researcher regarding car ownership in neighborhoods of Rotterdam, the assumption is made that in neighborhoods where more individuals live with lower SES, the ownership of other mobility resources (e.g. car, bicycle) will be lower, thus PT dependency will be higher. To gather socio-economic characteristics of the neighborhoods in Rotterdam, open-source data has been used, which has then be used to assess the potential risk of transport poverty for the neighborhoods in Rotterdam.

3.2.1 Low income – public housing

The level of public housing in the area is an interesting indicator for estimating the level of income within the neighborhoods in Rotterdam, as there are strict rules on who can apply for such housing in the Netherlands. The level of public housing can therefore be seen as an indicator of lower economic power within the neighborhoods. For the Rotterdam region, a housing costs atlas is publicly available. Based on data published by the Land Registry and Mapping Agency in the Netherlands (*Kadaster*), this atlas shows the level of public housing within neighborhoods in the Rotterdam area (See Figure. 4). For Rotterdam, a high volume of public housing is visible in specifically three areas around the city center: Crooswijk district in the North, and Feyenoord district in the South of the city. Specifically, the Afrikaanderwijk neighborhood, which is part of *Feyenoord* district, seems to have a high level of public housing. The level of public housing per neighborhood is inserted in Table 1.

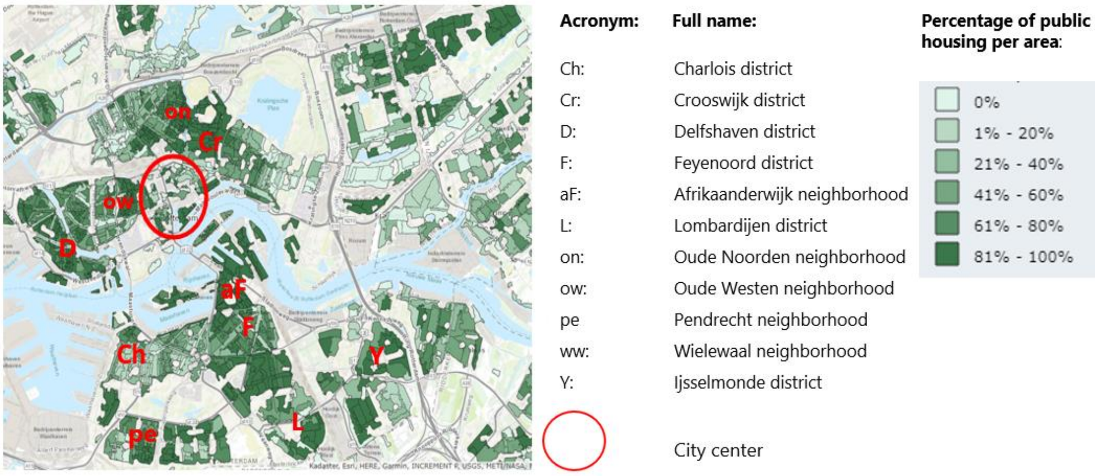

Figure 4. Levels of public housing through Rotterdam. (Derived from WoonatlasRotterdam (2021)

3.2.2 Low income / no job - Jobless inhabitants per district

As income is closely related to having a job; Income is mostly generated out of paid work (CBS, 2020). The lack of having a job has been used as another indicator for the determination of income levels among neighborhoods in Rotterdam. Data of the percentage of jobless inhabitants per neighborhood is publicly available via Onderzoek010.nl. Table 1 only shows the areas with higher than average joblessness or public housing. The entire list for all areas of Rotterdam can be found in Appendix 1. When evaluating the areas around the city center, Afrikaanderwijk (Charlois), Crooswijk, Lombardijen, and Pendrecht (Charlois) show the highest percentage of joblessness individuals per neighborhood.

3.2.3 Social Severity index

The study of Kampert et al., (2018) already used a form of classification to score social- and transport disadvantage indicators, linked to transport poverty. This enabled Kampert et al., (Idem.) to compare neighborhoods within a city on their transport poverty potential. For this study, a method of classification is also used by introducing the Social Severity Index (SSI).

The SSI is an estimation of the severity of PT service level reductions on the neighborhoods' inhabitants. The SSI is based on the average income levels in the neighborhood and the level of public housing in the neighborhood. The city's average is used as a comparison. Neighborhoods with both parameters lower than city average score the lowest SSI level of 1 (Low TP potential). Neighborhoods that show one of the two parameters being higher than average score SSE level 2. Neighborhoods scoring higher than average on both parameters score the highest level of SSI, which is SSI level 3 (High TP potential). The potential social severity is included in Table 1.

The reason for the implementation of this index is the assumption that reduction of PT services has a smaller social impact in higher SES areas. It can be assumed that other resources can be used to mobilizes higher SES individuals. However, areas scoring high on the transport poverty-related indicators, most likely, house the individuals who do not have other mobility resources at their disposal.

Table. 1

Socio-economic characteristics and SSI score per neighborhood of Rotterdam

Neighborhood name (District name)	Percentage jobless inhabitants of work force	Percentage of public housing in the area	Social Severity Index (SSI) level
Afrikaanderwijk (Feyenoord)	19%	82%	3
Agniesebuurt (Noord)	14%	63%	2
Beverwaard (Ijsselmonde)	12%	54%	2
Bloemhof (Feyenoord)	16%	59%	3
Bospolder (Delfshaven)	17%	62%	3
Oud-Crooswijk (Kralingen-Crooswijk)	19%	81%	3
Delfshaven (Delfshaven)	15%	61%	3
De Esch (Kralingen-Crooswijk)	10%	50%	2
Dijkzigt[1] (Centrum)	4%	74%	2
Greater-Ijsselmonde	12%	52%	2
Hillesluis (feyenoord)	14%	47%	2
Kralingen-West (Kralingen-Crooswijk)	11%	48%	2
Lombardijen (Ijsselmonde)	15%	51%	3
Nieuwe Westen (delfshaven)	13%	47%	2
Oude Noorden (Noord)	14%	58%	2
Oude Westen (Centrum)	15%	61%	3
Pendrecht (Charlois)	15%	55%	3
Rubroek (Crooswijk)	12%	52%	2
Spangen (Delfshaven)	13%	61%	2
Tussendijken (Delfshaven)	18%	60%	3
Vreewijk (Feyenoord)	16%	73%	3
Wielewaal (Charlois)	17%	96%	3
Zuidwijk (Charlois)	17%	66%	3
City average	**11%**	**44%**	-

[1] *Dijkzigt is a small area that is almost completely covered by the Erasmus University Hospital, which potentially holds accommodation facilities for its personnel and is therefore excluded from the research.*

Note: Socio-economic data derived from Onderzoek010, 2020b; Onderzoek010, 2020c

Figure 5 shows the visualization of the SSI scores in Table 1. Figure 5 shows the North (upper) and South (lower) part of Rotterdam and the social severity index with the corresponding neighborhoods and districts.

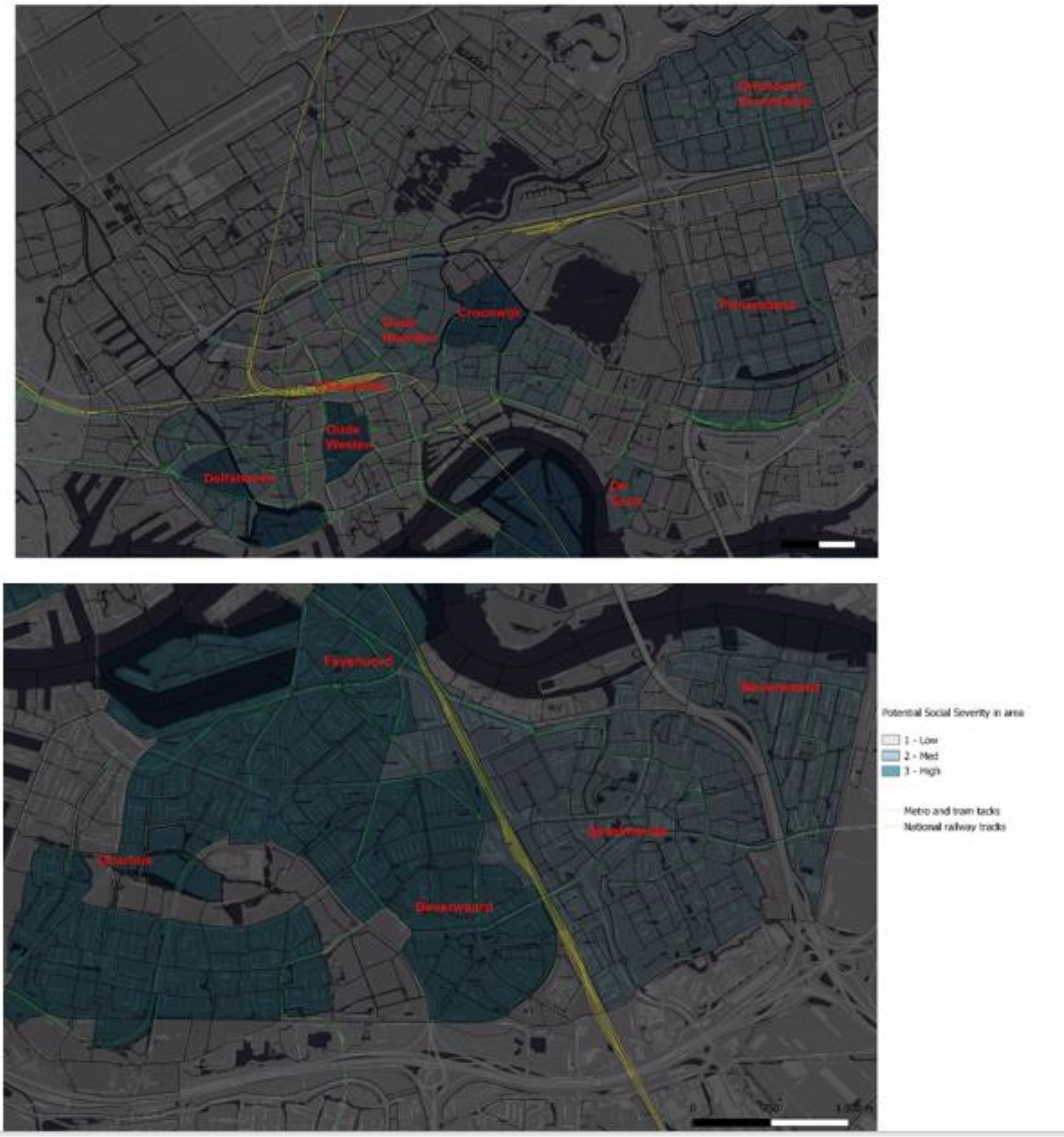

Figure 5. Social severity mapping in Rotterdam North and Rotterdam South

3.2.4 Combining data on job accessibility and potential for transport poverty

The SSI (Table 1), along with the simulation of decrease PT service levels and the corresponding accessibility of jobs, creates a more focused view on where the highest potential for transport poverty in the city exists. The data on job accessibility per neighborhood can be combined with the SSI data of the neighborhoods as visible in Table 1. These two data sources have been included in the same map using bivariate mapping. Bivariate mapping is a method to overlay two sets of data in a Geographical Information System, QGIS[3]. The map can be read using a bivariate legend. The legend in Figure. 6 shows the two types of data. On the x-axis, the social severity index indicated a range from low TP potential to High TP potential (corresponding to the blue color in Figure 4). On the Y-axis the level of decrease or increase of jobs. The bivariate legend will be visible in the result section again under SSI subchapters.

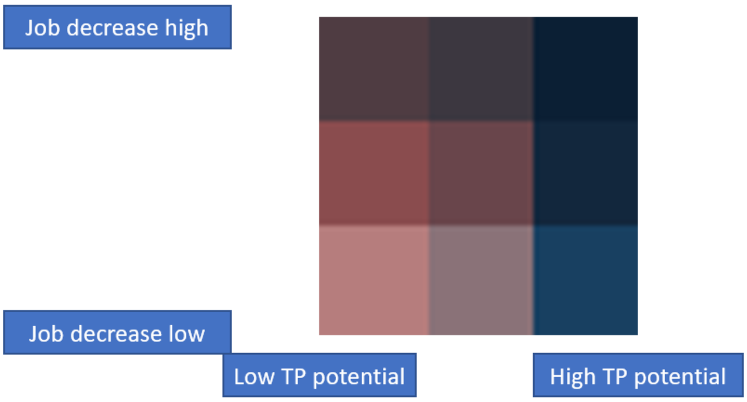

Figure 6. Bivariate legend

3.3 Data Analysis Tool

The simulation tool to simulate the accessibility of jobs by PT in Rotterdam is found in the MRDH traffic model (hereafter MRDH model). The number of accessible jobs in Rotterdam has already been implemented in the MRDH model. Therefore, the MRDH model itself will be discussed before the explanation of job distribution in Rotterdam in 3.3.2. Accessibility of jobs in the Rotterdam area.

3.3.1 MRDH model

Metropolitan region Rotterdam The Hague (MRDH) has created a regional traffic and transportation analysis model for their region. Integrated into the model is the road network of the metropolitan region, including cycling paths and PT network. The model can analyze PT travel streams within the region. Multi-modal journeys (e.g. PT-walking) are also reflected in the model. By using the model, a map can be created which

[3] QGIs is a Geographic Information System that creates, manages, analyzes, and maps various types of (geographical data) (Esri, 2021).

shows the accessibility of regions and the number of jobs that can be accessed by individuals from a region for a predefined travel duration. In 2020, the MRDH model has been updated with the latest socio-economic data. However, the PT network in the model still holds the 2016 timetable data.

3.3.2 Accessibility of jobs in the Rotterdam area

Figure. 7 gives an overview of where most job opportunities in the Rotterdam area can be found. In the model, the Rotterdam region is divided into postal code areas (PC4), indicated as black lines through the map. Given Figure 7, it becomes visible that the highest number of job opportunities per km^2 can be found in the city center of Rotterdam. Rotterdam South sees lower job opportunities than North. Areas located in the South with the highest level of jobs per km^2 are shopping centers or hospitals. There is a high probability that inhabitants of areas outside the city center need to travel to other areas to find a job, as the number of jobs in their neighborhoods is much lower.

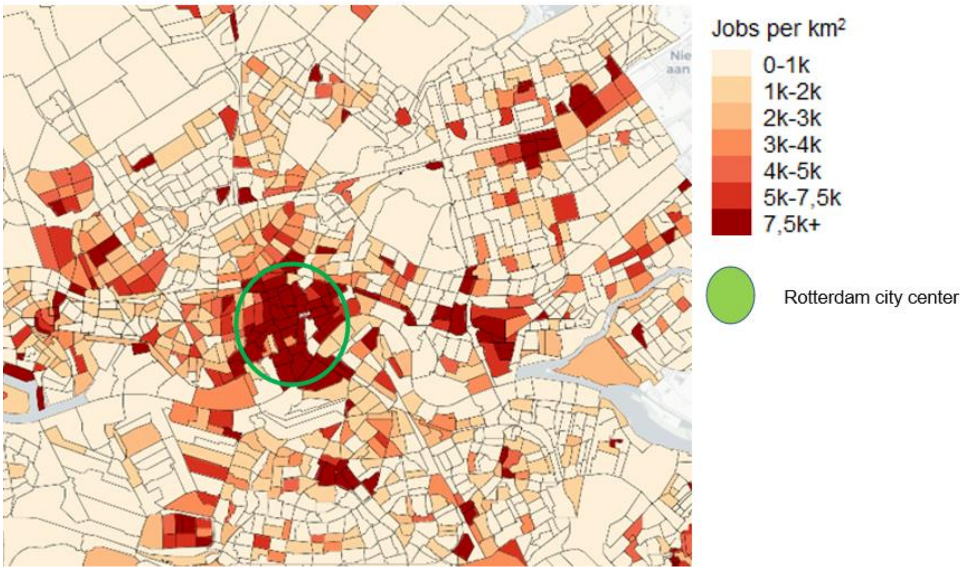

Figure 7. Number of jobs per km^2 for the Rotterdam region as programmed in the MRDH model (MRDH, 2018)

3.3.3 Travel time constraints

Travel time constraint is implemented to research two social disadvantage factors linked to transport poverty: ‘Low skill’ and ‘Low income’ as These results have also been made visible by Statistics Netherlands (van Roon et al., 2011). Figure. 8 shows that lower level education (*Basisonderwijs, Vmbo, mbo 1, Havo, vwo, mbo 2-4*) largely represent the large peak near 10km. Based on De Koning et al., (2017) study, a time constraint of 30 and 45 minutes as has been set. As in normal situations, an individual would be able to travel up to 15 kilometers by PT within 30 to 45 minutes. The 15-minute difference between the scenarios is built in to cover transfer times, making it possible to evaluate not only the accessible jobs by direct PT service but also a modal switch from bus to bus, metro, tram, or foot.

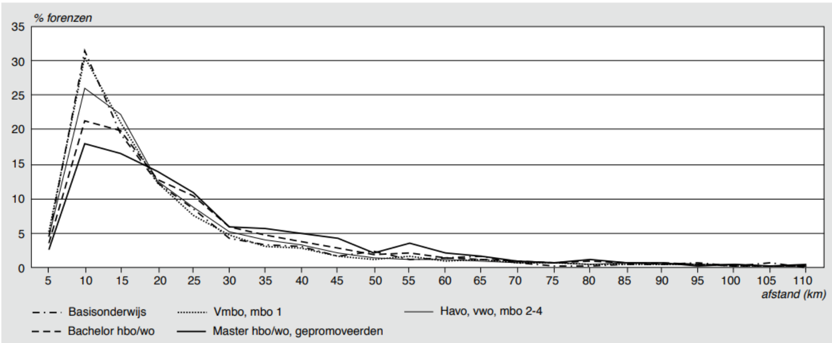

Figure 8. Educational level and corresponding travel distance to work as in van Roon et al., (2011)

3.4 Scenario and Simulation Description

By using the MRDH model two scenarios have been simulated. These scenarios consist of manipulations of the PT service levels of Rotterdam. The basis for the scenarios is the PT service level as was known in 2016.

3.4.1 Basis model

The basis model is set as the starting point for the manipulation scenarios. Both 30 minutes and 45 minutes basis-model has been created to create a basis for the accessibility of jobs per area.

3.4.1.1 *Basis model, 30 minutes travel time*

Figure 9 shows an aerial overview of the number of accessible jobs within 30 minutes for Rotterdam by PT, in the pre-Covid-19 situation. Added to the map in green are tram and metro lines, as well as national rail lines in yellow. The number of accessible jobs from all the areas in Rotterdam runs from 0 to just above 347.000 in the pre-Covid situation. Rotterdam's city center thus sees the highest number of accessible jobs reachable in 30 minutes (white), While in the north of Rotterdam Crooswijk, a low SES-district in North, sees the lowest accessibility of jobs with a level between 100k – 150k jobs accessible.

Under the river Maas, the South of Rotterdam shows a generally lower level of accessible jobs compared to the North part of Rotterdam. The white spots in the south are represented by Kop van Zuid which holds large offices of e.g. Port of Rotterdam and Tax and Customs Administration (*Belastingdienst*). The other white dot in the south is the Zuidplein bus and metro station. According to the model, the least number of accessible jobs in the South are from Beverwaard in the East and the South of Lombardijen in the South, both marked in dark red. Where Feyenoord is almost completely in the 200-250k range, Charlois is almost completely in the 150 – 200k range, where Charlois West even drops to 100 – 150k.

In the Southwest area, parts of the port of Rotterdam are visible in Dark red. As being industrial sights, these areas are sparsely populated. Except for the small area which is lighter in color. This represents the village of Pernis.

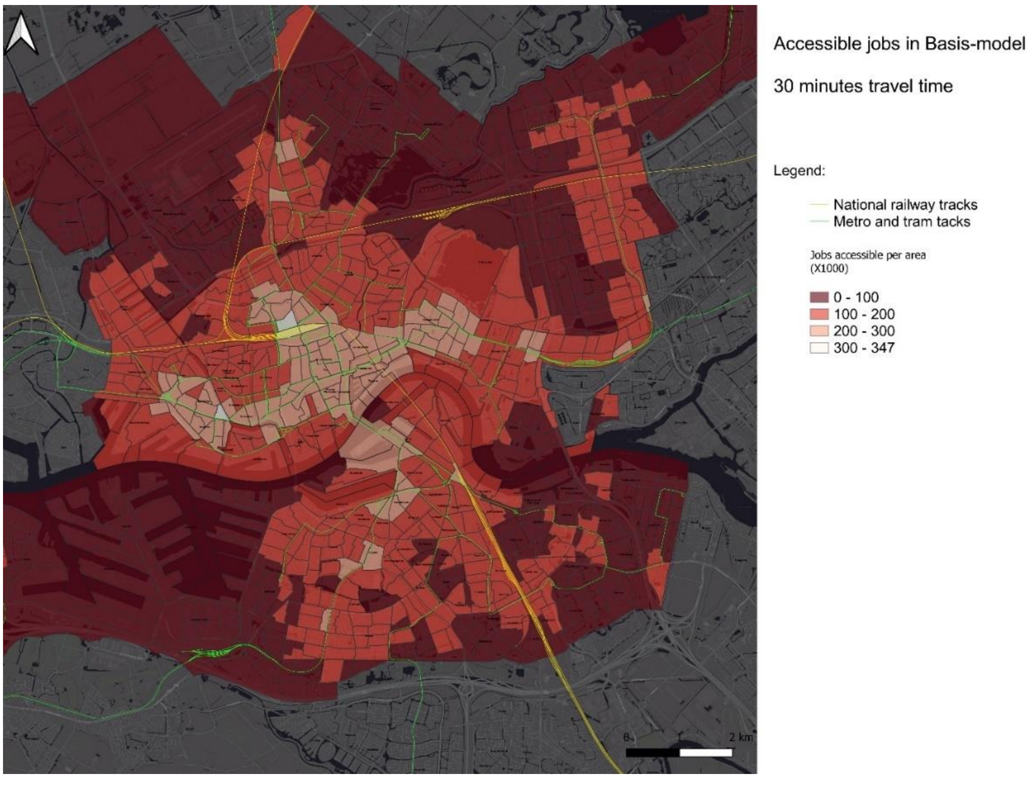

Figure 9. Jobs Reachable by PT in Rotterdam: Null-Basis (2016), 30 minutes travel time

3.4.1.2 Basis model 45 minutes travel time

In Figure 10 the basis model for 45 minutes travel time is made visible. The number of jobs reaches a maximum of 812.000 in the city center. The accessibility North of the river Maas sees a similar east-to-west pattern with a relatively high number of accessible jobs. Also in this 45 minutes basis model, the south sees a relatively lower level of accessible jobs compared to the North. As the distance from the city center grows, the number of accessible jobs decreases.

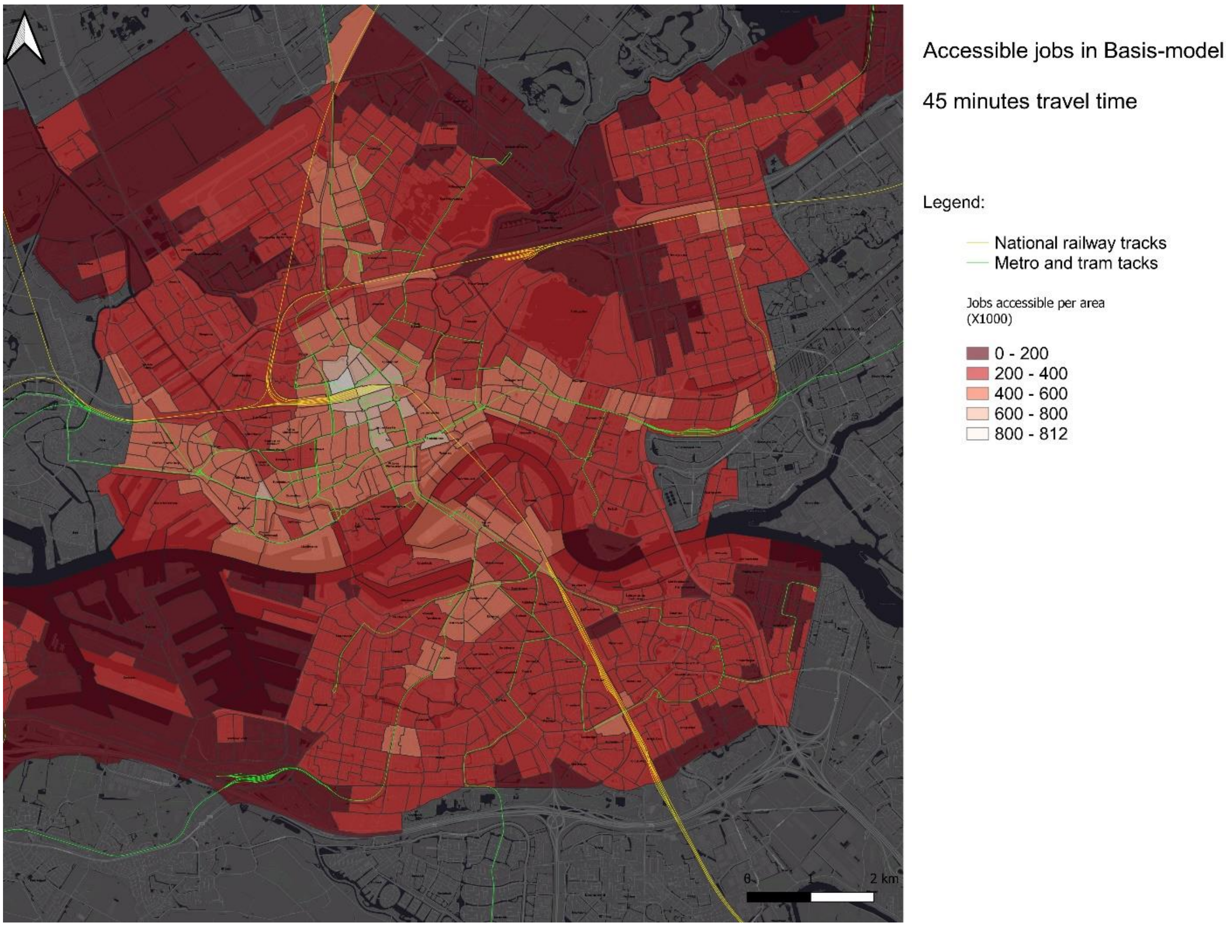

Figure 10: Number of jobs accessible per area in 45 minutes by PT

3.4.2 Simulation design

Apart from the basis model run of the MRDH model, two simulated scenarios were run in the model. These two simulated scenarios have been used to evaluate the changes in job accessibility for the city of Rotterdam. These next two simulations are a manipulation of the basis model. This means that the simulations have been adjusted according to the researchers' input. Manipulations have been executed to observe respective changes in accessibility during the pandemic.

3.4.2.1 10% PT service reduction - Moderately optimistic scenario

As of January 3th 2021, Rotterdam's PTO RET runs approximately 90% of its pre-Covid 2019 schedule (**MRDH**, 2020). To generate insight in what this decrease has done to the accessibility of jobs, the MRDH model comes into place. The model represents the accessibility of jobs as of timetable 2021. The moderate scenario represents the assumption that the current covid-related availability fee (BVOV) issued by the Dutch government will be extended for a longer period. Therefore, the further reduction of services can be minimized to a minimum. However, it is not unlikely that, especially for the short term, there will be no frequency increase on PT lines if, compared to 2019, the passenger numbers remain low.

3.4.2.2 30% PT service reduction - Moderately optimistic scenario

This scenario is created based on the condition wherein the Dutch government will significantly reduce or fully suspend the availability fee (BVOV) along with slow growth in passenger numbers towards 2025. The effects of lack of government aid to cover for the gaps in income, created by the pandemic, have been calculated by PTOs and concessioners. In this scenario, a timetable reduction of 30% is realized as this reduction will be needed to operate financially sound without BVOV aid.

3.4.3 Percentual decrease calculation

After the scenarios have been simulated. The outcome of the number of accessible jobs per area, for both scenarios and travel times, will be subtracted from the pre-Covid accessibility. The outcomes of the simulations have been made visual by using QGIS software.

Percentual decrease calculation:

$$\text{j\_change} = \frac{a\_Jobs\ accessible\ in\ area\ X\ in\ simulation\ y - A\_jobs\ accessible\ in\ area\ 2019}{A\_Jobs\ accessible\ in\ 2019} \cdot 100\%$$

Wherein *j* is the percentual decrease of accessible jobs per area, *x* the area code, the number of jobs accessible for the area, *y* the simulation scenario (10% or 30%).

3.5 Validity and Plausibility of the Model

The MRDH traffic model is a forecasting model for freight, traffic, and PT throughput in the MRDH-region. The model's base year which, in the current case, is 2016 for PT, is validated in two ways. First are the mixed-method outcomes of Dutch mobility Research (OViN) by Dutch statistics (CBS). The OViN database for 2016 consists of information gathered by 37.229 respondents. 22,8% of the combined 193.6 billion kilometers traveled were done using PT (CBS, 2017b). The second data tool, are throughput data of the MRDH-region.

This data consists of counting installations throughout the region, which can count the traffic flow in designated streets and areas. This tool is also used for calibration purposes. More info on the calculation method of the model can be found in Appendix 2.

4. Results

The scenarios have simulated the effects of PT frequency reduction on job accessibility within the city of Rotterdam. During the results, I will firstly discuss the results relevant to the first hypothesis. All scenarios will be discussed, starting with a 10% PT decrease scenario and 30 minutes travel time, followed by 45 minutes. Thereafter the 30% reduction scenario follows with the travel times accordingly as for the 10% scenarios.

4.1 10% Service Reduction Scenario Results

4.1.1 10% reduction - 30 minutes travel time

The overview in Figure 11 shows the results after a 10% reduction of PT services. According to the model, areas in Rotterdam's city center still hold the greatest number of jobs accessible from those areas. Nonetheless, the majority of the city's areas see a decrease in accessible jobs between 0% and 5%. The number of areas with the highest number of accessible jobs (250-300k and 300-350k) has decreased. In the north, the areas around Crooswijk district see a decrease in the number of accessible jobs of around 2,5% to 5%. The areas covered by the 100-150k range increases around Crooswijk. Feyenoord district decreases to the lower range of 100 – 150k including Afrikaanderwijk neighborhood. The areas around Charlois in the West of Rotterdam South also see a decrease of two areas into the 50 – 100k accessible jobs. Furthermore, a large part of Ijsselmonde district decreases to 100 – 150k. In the Southwest of Rotterdam South, the industrial area is also visible in dark red, showing a decrease of >5%.

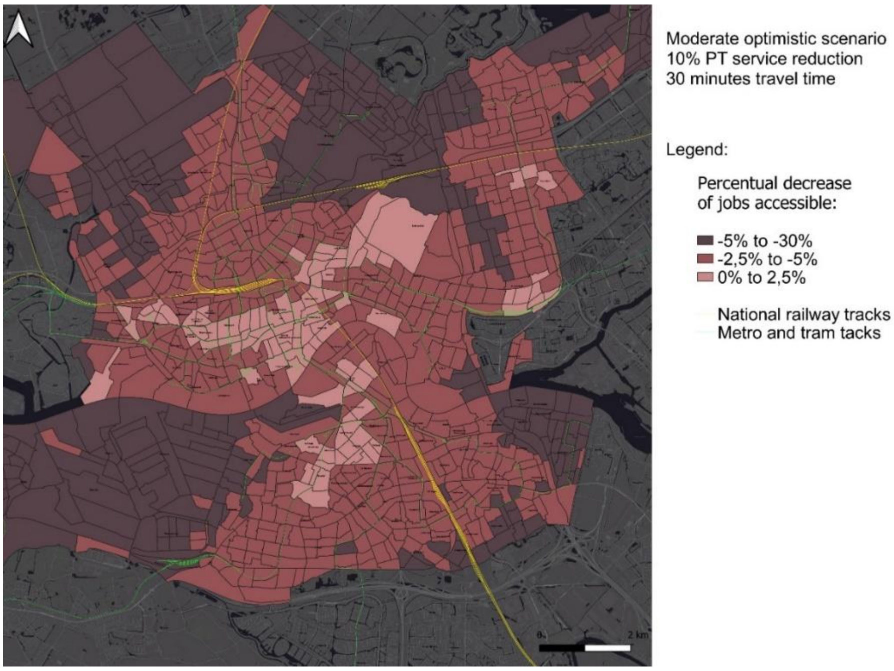

Figure 11. Jobs reachable by PT in Rotterdam, 10% frequency decrease, 30 minutes travel time

4.1.2 10% reduction - 45 minutes travel time

For the 45 minute scenario, we see that the outskirts of the city make up for their decrease in jobs, as for this scenario, the time window is more sufficient to reach the city center, which is known for its higher job density.

According to the simulation, the city center is colored in white. Although the heart of the city, around the central station, is the remaining part in white. The main shopping and business district in the center has fallen in a lower category (450k-600k). In Rotterdam North, Crooswijk is visible as an 300k – 450k area. The area colored in the lightest color in North is Kralingse bos, which is a large park. As the accessibility of jobs has been already very low in the middle of the park, the percentual decrease is not that high, resulting in the light color.

Figure 12. Jobs reachable by PT in Rotterdam: 45 minutes travel time, 10% service reduction

In Rotterdam South, the only remaining areas with the highest number of accessible jobs remain two areas near Zuidplein bus and metro station (areas with the lightest color in South). A larger part of Charlois is now in the second-lowest classification. Even the areas around Slinge metro station are not in the highest job accessibility category anymore. A larger part of Lombardijen and Vreewijk reached the 150k – 300k area. These areas see a decrease in accessible jobs of approximately 4000. No major changes in Feyenoord are visible. However, the original number of accessible jobs in the pre-Covid situation seems to be higher near the metro station. In Bloemhof (Feyenoord), the number of accessible jobs decreases from 216k to 211k, which represents a decrease of about 2,5%. When converting the decrease of accessible jobs per area to a percentual decrease, the maps show a relatively equal distribution of the decrease of the number of accessible jobs for the entire city. Some areas with a lower decrease, e.g. the two areas visible in North, are recreational areas that already had a low number of accessible jobs in the pre-Covid situation. The North of Hilligersberg-North in the North of Rotterdam has a relatively high decrease of job accessibility being marked with a decrease of >5%. In the Northwest, the area around the airport is also marked in the latter category. In the South, we see some high decrease in

In the 30 minute scenario, most jobs remain accessible for those living in areas in the city center. This is understandable if most jobs can be found around the city center. However, this results in poorer job accessibility for the more suburban areas of Rotterdam, further away from the city center. The 45-minute scenario shows a more equal decrease of job accessibility throughout the city, with some exceptions where job accessibility does not decrease as much as in the rest of the city, like Zuidplein metro and bus station.

4.2 30% Service Reduction Scenario Results

4.2.1 30% reduction - 30 minutes travel time

The simulation for the 30% reduction scenario shows a maximum job accessibility per area of 800k. As the reduction of the number of accessible jobs, for either 30 minutes and 45 minutes travel time, is greater in this scenario, the percentual decrease steps indicating the decrease in the number of accessible jobs has been altered. Compared to the 10% service level reduction scenario, this 30% service level reduction scenario shows a minimum decrease of 10% per step. This has been done to create equally large steps in the legend.
When simulating the second scenario, which represents a reduction of 30% of PT services, we can evaluate that the city center areas remain those with the highest number of accessible jobs. When evaluating the percentual decrease, this is visible with the low level of percentual decrease. The city center is visible in the first category (0% to -10%)

In the South, Charlois is now almost in the 150 – 300k zone from the south of the area till the river Maas. Also a larger part of Lombardijen decreases to 150 – 300k. Accessibility in Feyenoord slightly decreases. Now one area has reached 150 – 300k. In Afrikaanderwijk (Feyenoord) the loss of accessible jobs is about 3k. The already low job accessibility in Wielewaal (charlois) of 98k pre-Covid, decreased with 4k to 94k jobs.
In this simulation, the percentual decrease is lowest in the city center and along the East-West metro line in the north. This metro line runs from East to West in North. In South. The southbound metro line runs through the area with the lowest number of percentual decrease. These metro lines seem to reduce the impact on the decrease of job accessibility for the areas in the vicinity of a metro station.

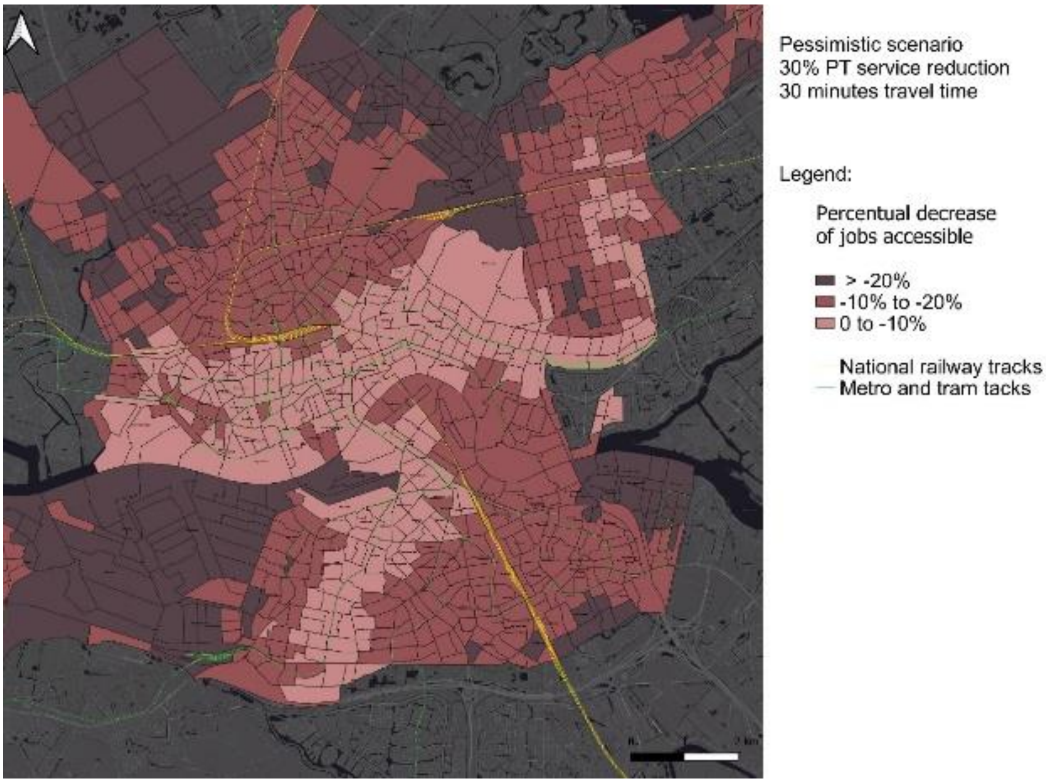

Figure 13. Jobs reachable by PT in Rotterdam (-30%), 30 minutes travel time

4.2.2 30% reduction - 45 minutes travel time

Compared to the 30 minutes travel time, the 45 minute travel times show slightly different job accessibility. In the North, Crooswijk now sees job accessibility in the range of 150-300k, which has been made visible in Figure 14.

In The South, the entire area of Charlois now has job accessibility of 150-300k, instead of just the southern parts. From Lombardijen, the red area is now also approaching Feyenoord Afrikaanderwijk.

Figure 14. Jobs reachable by PT: -30%, 45 minutes travel time

4.2.3 Frequency reduction and the effect on the accessibility of jobs

when looking back at the job accessibility in the basis model, jobs are not equally spread throughout the city. According to the simulated scenarios, the further reduction of PT services helps to increase that unequal distribution. As the suburbs and areas farthest away from the city center will see be the first to suffer from a decrease in accessible jobs. Next to that, the vicinity of a metro station helps to mitigate the decrease. Based on the -10% and -30% scenario the first hypothesis (H_1): PT frequency reductions will lead to more unequal accessibility of jobs because of unequal mobility opportunities can be confirmed for the -10% scenario and confirmed for -30% scenario.

4.3 Social Severity Index Results

After the results of the percentual decrease of accessible jobs in Rotterdam, the evaluation of the severity of the decrease has been made using SSI.

4.3.1 SSI, 10% reduction – 30 minutes travel time

Compared to the pre-Covid situation, the percentual decrease in accessible jobs is combined with the social severity index (Figure. 2). The combination of these two data creates an overview of areas that have the highest transport poverty potential. The Basis-model already showed that Rotterdam-South has, compared to North, worse accessibility of jobs and a greater number of areas with a high potential for transport poverty. The model confirms this again when PT services have been reduced by 10%. The areas with inhabitants at greatest risk for transport poverty are mostly seen in Rotterdam South. In North, Crooswijk can be identified as an area with a higher than average risk. In the Northwest, some areas within Delfshaven are at risk.

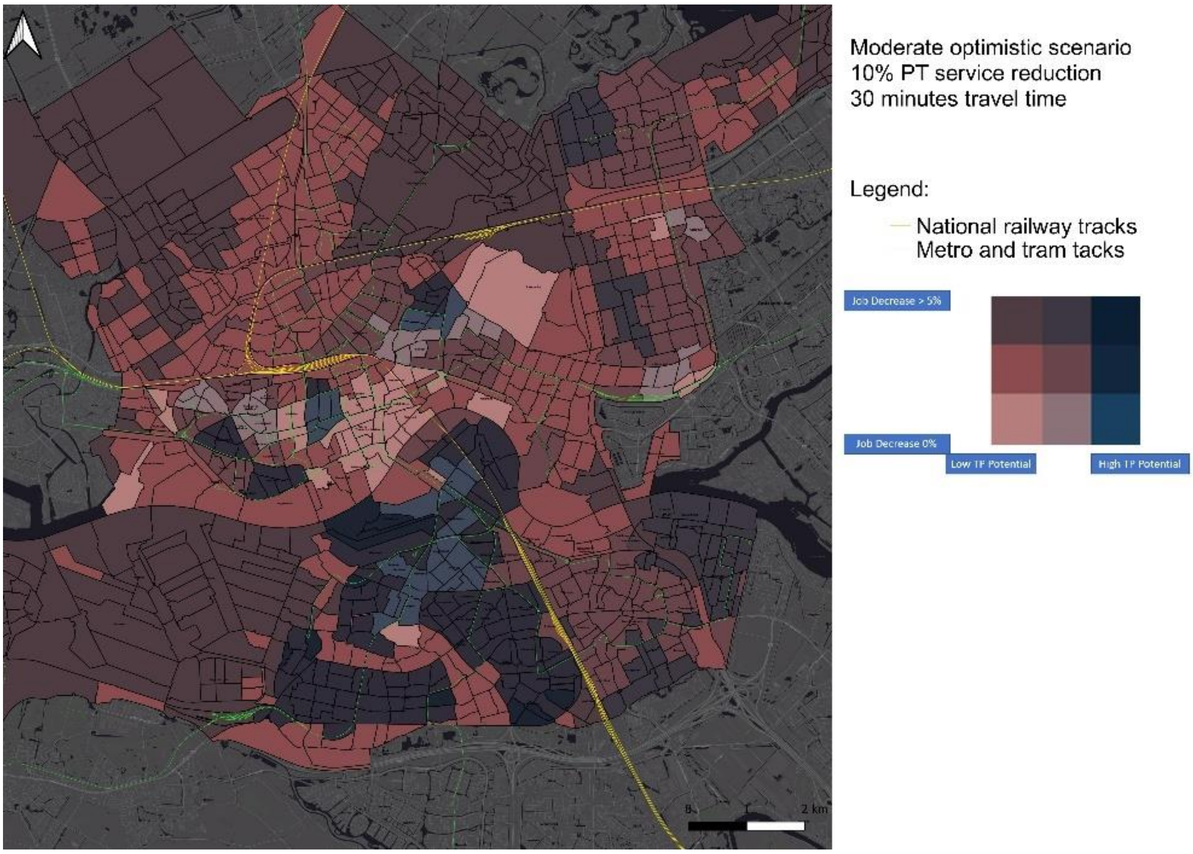

Figure 15. Social Severity map for 30 minutes travel time and 10% service reduction

4.3.2 SSI, 10% reduction – 45 minutes travel time

Evaluating Figure 16, Rotterdam-South is most salient. Having the greatest SSI level 3 areas, the potential for Transport poverty is high. Along with a decrease in the area of around 2,5% to 5%. As especially the job accessibility per area decreased in the Feyenoord area, the potential for transport poverty grew, compared to the 30 minutes simulation. For North, a similar pattern can be observed as is visible when simulating this scenario with 30 minutes of travel time.

Figure 16. Bivariate map of the percentual decrease of job accessibility or 45 minutes travel time and 10% service reduction overlayed with social severity index

4.3.3 SSI, 30% reduction – 30 minutes travel time

The largest spots for potential transport poverty are visible in the South. In the North, Crooswijk also shows high potential, however only a small part of the district. In the Northwest, Delfshaven shows a light potential of transport poverty. Evaluating South, From the SSI level 3 areas, Lombardijen has the highest potential for transport poverty in this situation, as being further away from the city center than Feyenoord and Charlois.

Figure 17. Bivariate map of the percentual decrease of job accessibility or 30 minutes travel time and 30% service reduction overlayed with social severity index

4.3.4 SSI, 30% reduction – 45 minutes travel time

When evaluating the Bivariate map of the 30% PT service reduction scenario, a fairly similar pattern is visible as in the 10% service reduction scenario. However, it is visible that Rotterdam-South's transport poverty potential tends to be higher for this scenario. As the percentual decrease for the districts, Feyenoord and Charlois are higher than in the 10% scenario and the SSI levels of the districts remained unchanged. The outcome of both input variables equals out a higher transport poverty potential

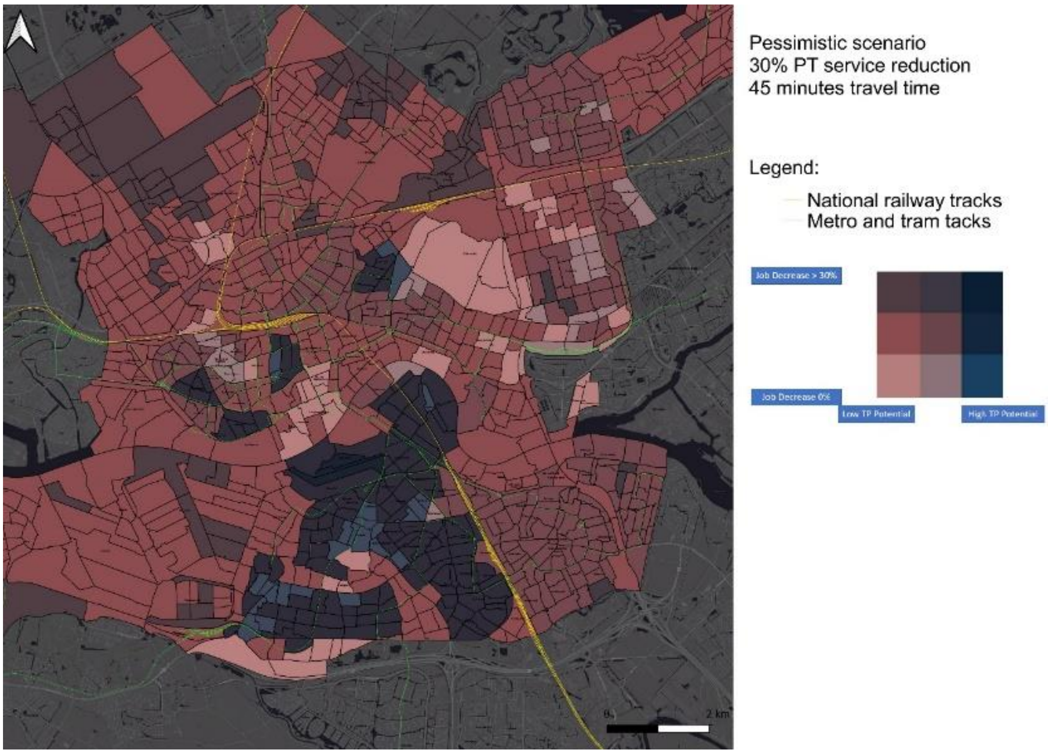

Figure 18. B*ivariate map of the percentual decrease of job accessibility or 45 minutes travel time and 30% service reduction overlayed with social severity index*

4.3.5 PT frequency reduction and transport poverty potential

The simulations of the traffic model including the SSI give an insight into which neighborhoods tend to be more prone to transport poverty. based on the socio-economic characteristics of the neighborhood included in this study, and which are relevant for the transport poverty potential assessment, the SSI shows that a large part of Rotterdam South is prone to transport poverty. The effect of service reductions is not equally distributed throughout the city. Therefore, the second hypothesis: (H_2) 'PT frequency reduction will increase transport poverty potential in Rotterdam' can be confirmed for the simulations made in this research.

5. Conclusion & Discussion

This research wanted to evaluate the effects of the decrease of PT frequency reduction on the accessibility of jobs for inhabitants of Rotterdam. A special focus was laid on low SES inhabitants of the city who tend to be, based on scientific research on transport poverty, more prone to transport poverty. The research wanted to know what the impact of the COVID-19 pandemic had been on PT in the city of Rotterdam and which individuals in what neighborhoods would be more prone to transport poverty within Rotterdam. The main question of this research was: 'How can the impact of the PT frequency reductions on transport poverty be minimized for groups without alternative transport in the city of Rotterdam?' When evaluating the first hypothesis 'PT frequency reductions will lead to more unequal accessibility of jobs because of unequal mobility opportunities' in the executed simulations, the accessibility of jobs decreased throughout the city when PT frequencies were reduced. However, there are differences in the speed of decrease observable. The city center is best in preserving high levels of job accessibility, while the outskirts of the city see the sharpest decrease. This is the case for both the -10% and -30% scenarios. Compared to the -10% scenario, the decrease of job accessibility seems to be steeper. In the 30 minutes pessimistic scenario the areas around direct rail services profit from a direct connection with the city center, which is the area that has the most jobs to offer. In the 45 minute scenarios, the areas around high As the research has shown, the number of jobs accessible by PT is negatively affected by the service frequency reductions as simulated. The simulations have shown that the decrease in accessible jobs varies throughout the city, with the outskirts being most affected. As has been discussed by Bastiaanssen (2012) in 2012, the South of Rotterdam remains most worrisome regarding the potential for transport poverty. In this study, again, a similar pattern is visible.

The Social Severity Index (SSI) has helped to create a better overview of the areas where a decrease in PT services would be the most unwelcome, based on sociological and socio-demographical standpoints. The index has helped to show that even with the equally distributed decrease in PT service levels, the outcome is even more unequally distributed of job opportunities than in the pre-pandemic situation. Although the metro system in Rotterdam, with its relatively high frequencies (even during the pandemic) and sharp focus on offering fast and direct connection to the 'job rich' city center, has a great influence on the accessibility of jobs in the 30 minute travel time constraint. This is valid for 10% and 30% decrease scenarios.

What is interesting to see is that for the moderately optimistic scenarios, the 'metro effect' seems not strong enough for the 45-minute travel constraint. It can be expected that this is the result of a transfer that is needed to access metro services to the city center, connecting service to the metro station which does not meet the same frequencies as the metro service does and thus increasing the potential for longer waiting times at stopovers. For the pessimistic scenario (-30%), the 'metro effect' is only visible for the areas that have an adjacent metro station, such as Zuidplein and Slinge in the South.

Evaluating the second hypothesis: 'PT frequency reduction will increase transport poverty potential in Rotterdam' it can be concluded that from a sociological standpoint, the two scenarios show a negative story for inhabitants of low SES districts in Rotterdam. Especially for low-skilled workers, it is essential to have good PT connections to job opportunities in the vicinity as long-distance travel is economically desirable because of the generally lower household income and limited resources. Even in the -10% frequency scenarios, a decrease of accessible jobs of around 4k in most Low SES areas is the norm. To put that number into perspective, the number of accessible jobs lost is well above the total number of employees at PTO, RET (3500). Numbers are getting worse in In the 45 minutes travel time where a decrease of accessible jobs of more than 10k is not uncommon in low SES areas. This is comparable to the entire workforce of the Rotterdam municipality (11.000).

Based on the light of recent research by Bastiaanssen et al., (2021) the decrease in job accessibility in Rotterdam is worrisome for the employment outcomes of those reliant on PT. Especially those in suburban areas, where could benefit greatly from good PT connections and create an 'easy win' in terms of job accessibility. As a result of the simulated outcomes, low SES individuals tend to substantially suffer from the decrease in PT services. Therefore public and political intervention is needed to prevent those who rely on PT from becoming immobile, and job seekers from becoming repelled from the labor market around them.

The outcomes of the simulations should function as awareness towards governmental organizations. Preventing under-serving, in terms of a decreased accessibility of those neighborhoods with high transport poverty potential should be not be overlooked when evaluating future transport plans for the city. The loss of a job next to the lack of private transport and insufficient PT are the biggest predictive factors for social exclusion. With a decreased accessibility of jobs by PT, the potential for transport-related social exclusion increased for those not able to switch to other forms of transport. They end up in the vicious cycle of joblessness, heading towards social exclusion. They become transport poor. The expected economic downturn after the pandemic is in control could eventually accelerate this downturn as fewer jobs will be available in the spatial mobility area of those relying on PT in these times. The outcome of an equal decrease of PT services is unequal opportunities relating to job accessibility. PT frequency reductions will lead to an increase in accessibility of jobs due to unequal distribution of transportation options.

The outcomes of this research should be seen as a call for more scientific attention to this social problem of transport poverty and social exclusion. The Dutch government already set the first step in 2018 by researching transport poverty in Utrecht and Heerlen. However, this was in the pre-Covid situation. Now that this research has proven that the situation in a more densely populated city than Utrecht, Rotterdam, has worsened. The 10% PT service decrease simulation, which acts as a simulation of the current situation (mid-2021), shows that low SES districts see a decrease in PT, which should not be tolerated. The 30% PT forecasting simulations show a further decrease. For Low SES individuals being non-car owners, the decrease in PT cannot be mitigated by switching to another form of transport. Future research should focus on minimizing PT reductions in the high-level SSI neighborhoods to mitigate the worsening of transport options for those relying on bus, tram, metro, and train. Having a job is the mitigator in preventing many other social problems. Therefore it should be prevented that those who lost their job, also lose their accessibility.

This research again has shown the complexity of transport poverty. As this research was just able to research a portion of the factors linked to transport poverty, it shows how difficult it is to understand the phenomenon and act upon it. As the definition of 'Poor PT services' by Lucas (2012) is very broad, this even had to be downscaled to PT frequency characteristics to execute the research. By using a scale to gather social disadvantage characteristics, a part of the complexity is removed to simplify the usabiliry of the theory. However, more in-depth focus in simplifying the theory of transport poverty is needed to improve the usability of these theories by scholars and actual governmental bodies who are responsible for PT service provision in their governing areas.

Having executed the research, some reflection can be done on the execution of the research. As this research focused on simulations and was not able to analyze 'real life' data, some words of cautiousness have to be made when interpreting the outcomes. So have the PT frequency cuts been equally distributed by calculations in the MRDH model, resulting in an equal reduction of every PT line in the Metropolitan region. However in reality the service cuts might not be that equally distributed throughout the city and the day. As some services with higher frequency might see a different percentual decrease than lower frequency lines. A line that offers two services an hour is already decreased 50% by terminating one service. This principle benefits areas that historically had a better level of service and worsening the situation for areas that already had a relatively bad level of service

Currently, due to the pandemic, the researcher couldn't gather personal data of random individuals living in the SSI Level 3 areas of Rotterdam. Therefore this research is missing rather interesting qualitative data. More knowledge on where the individuals in these SSI level 3 areas need to travel to could be a valuable addition to the research. The accessibility of jobs is now weighted in the heart of the city of Rotterdam, as that is where, statistically, the most jobs can be found. Based on former studies by Bastiaanssen (2012) and de Koning et al., (2017) lower educated individuals are most likely to work closest to home. Respectively within the Metropolitan region of Rotterdam and the Hague. However, the researcher assumes that the most relevant areas to find lower educated work lay outside the city center of Rotterdam and should more be sought in the more peripheral areas, such as the Port and industrial district in the far West and Southeast (*Drechtsteden*). Unfortunately, those places are known for having bad accessibility by PT. And even if connected, the PT network does not take into account shift work, which might start in the early morning and could end just before midnight. To strengthen the outcomes of this thesis, more qualitative research on workers of Rotterdam South is needed, next to a more detailed overview of where the most suitable jobs can be found for those individuals, and whether these jobs are accessible by PT, for example by using 'Origin-Destination' data. Which holds data of where people come from and want to go.

Another missing link, which can be built upon the previous point is the link between place of residence and work. A job location generally differs from a residential location. However, these two can influence each other. E.g. when someone moves to live closer to work. However, when the job is lost, the job searcher is limited in his search by the accessibility of jobs reachable from his 'new' residential area. As lower-skilled jobs have seen shifts towards more peripheral locations in the last 20 years, the accessibility of suitable jobs can be significantly reduced compared with the number of jobs accessible when the individual moved to a certain area, especially for lower-educated workers. Hereby the residential location of the jobless individual can harm next job searches. Especially as individuals are stuck in their place due to the financial unfavorable position someone enters when losing a job.

Moreover, this thesis only evaluated the number of accessible jobs, it was not able to take a step further and also take into account the number of prospective applicants for those jobs. As not every individual can apply for every job, a missing link is the 'spread' of jobs in the Metropolitan region based on educational level, to evaluate whether individuals in the high SSI level areas do have proper access to areas that hold suitable jobs for them.

Apart from that, the SSI has been controlled by using the city average of joblessness and social housing, however, this slightly limits the replicability of the research, as the average will differ from city to city. For future research, a national average should be used.

6. Policy advice

This thesis wants to look away from the more economic view that is normally prioritized when evaluating the Key Performance Indicators (KPIs) of PT. When taking not of the instructions by the Dutch Minister of Finance, the yield realization dominates the level of PT service in the Netherlands. However, what PT needs in these uncertain times, when economics are not in favor of PTOs and their concessioners, is guidance and a better focus on what the core business of PT is: Preventing individuals in society, from becoming transport poor and getting socially excluded from society. The Social Severity Index has helped to regain that focus when evaluating service level reductions in PT. However, as this study is just a minor example of a serious but very complex problem, more political awareness is needed. Revised transport plans now created by PTOs and concessioners, to minimize losses during the pandemic, focus on minimizing the termination of lines, and focus more on finding the right spot between frequency and serving the city.

The potential for transport poverty within the city center is considered to be low. This is not the case for most of Rotterdam South and parts of Delfshaven and Crooswijk. Both simulated scenarios have shown that good PT connectivity is essential for the accessibility of jobs. As the metro is the only fast option to get from south to north, good accessibility and connectivity to that metro are needed to mitigate the effect of transport poverty. The optical illusion that the continuation of service, however less frequent, prevents the isolation of that service area, is questioned by these simulations.

This thesis should serve as a political eye-opener for governmental institutions to show the importance of a critical approach towards the transport plans within the sovereign area. The reduction of the level of service of line A might have very different consequences than the reduction of service of line B. The socio-economic catchment area of a line and the characteristics of the passengers using the service result in different social relevancy for different PT lines. Where the effects of the reduction/termination of services can differ in the social and economic impact for the (potential) users of these services.

The reduction of the level of accessible jobs must be a very concerning one for the governmental institutions as joblessness is known as the accelerator for many other social problems and decrease of livability within neighborhoods. For this thesis scope, the focus for municipalities, when evaluating the transport plans of PTOs, can be to prioritize frequent service levels for busses that offer connections to metro stations. Metro stations have a great positive effect on the accessibility of jobs in Rotterdam.

The organization of PT is a very complex one. Many stakeholders are involved in the process. Provinces, municipalities, PT operators, and of course passengers and inhabitants in the catchment area of the PT services. As the general use of PT in the city is higher and car dependency is lower, a sudden negative change in PT might have undesirable outcomes for a city like Rotterdam. What this thesis shows is that the decrease of PT services within a city has a major impact on the city’s inhabitants and their opportunities to reach work or to find a job at all. However, as mobility opportunities are unequally spread over the different levels of SES individuals in the city, the effects of PT changes don't affect every individual as much. Inhabitants of Lows SES-neighborhoods tend to be more reliant on PT for their actual spatial mobility to get a job.

As the Social Severity Index shows, a decrease in PT service level has a varying impact in various neighborhoods in the city. Neighborhoods with an already low level of SES and already a relatively bad connection PT services, fall behind, even more, when the service reductions have been applied. The level of decrease of service only worsened the job accessibility. As compared to the PT organizations, the governmental bodies responsible for PT services do not have an economic incentive and should therefore focus more on the social aspects of PT, which are endangered by the mismatch between the social relevance of PT and the need for financial sustainability. The focus should lay on minimizing PT service level reductions in low SES-neighborhoods within the city, as alternative transport can, for lower incomes, be very costly or non-existent at all.

Governmental institutions can be built upon this thesis to implement a prioritization tool for evaluating future service cuts. Whereas the services with the least social impact can be canceled or reduced first in favor of services running to and from low SES neighborhoods and high potential job areas for low-SES individuals. The SSI scale is the first step towards this procedure. By adding more information regarding PT services in these neighborhoods along with more neighborhood-specific socio-economic data on where the inhabitants of those areas want and need to go, PT can offer that custom service (*maatwerk*) that is much needed in these neighborhoods.

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Appendices

Appendix1: SSI and Socio-Economic data of neighborhoods in Rotterdam

Areas of Rotterdam and corresponding percentage of joblessness inhabitants and percentage of public housing in the area

Area name (District name)	Percentage jobless inhabitants of work force	Percentage of public housing in the area	SSI score
Afrikaanderwijk (Feyenoord)	19%	82%	3
Agniesebuurt (Noord)	14%	63%	2
Beverwaard (Ijsselmonde)	12%	54%	2
Blijdorp (Noord)	4%	9%	1
Bloemhof (Feyenoord)	16%	59%	3
Bospolder (Delfshaven)	17%	62%	3
Carnisse (Charlois)	9%	18%	1
Cool (City center)	6%	29%	1
Cs Kwartier (city center)	2%	5%	1
Oud-Charlois (Charlois)	11%	37%	1
Oud-Crooswijk (Crooswijk)	19%	81%	3
Delfshaven (Delfshaven)	15%	61%	3
De Esch (Kralingen-Crooswijk)	10%	50%	2
Dijkzigt (Centrum)	4%	74%	2
's Graveland (Prins-Alexander)	4%	24%	1
Groot-Ijsselmonde (Ijsselmonde)	12%	52%	2
Het Lage Land (Prins-Alexander)	9%	35%	1
Hillegersberg-N (Hillegersberg-Schiebroek)	8%	36%	1
Hilligersberg-Z (Hillegersberg-Schiebroek))	4%	2%	1
Hillesluis (Charlois)	14%	47%	2
Katendrecht (Feyenoord)	11%	38%	1
Kop van Zuid (Feyenoord)	3%	37%	1
Kralingen-O (Kralingen-Crooswijk)	2%	14%	1
Kralingen-W (Kralingen-Crooswijk)	11%	48%	2

Liskwartier (Noord)	9%	40%	1
Lombardijen (Ijsselmonde)	15%	51%	3
Oud-Mathenesse (Delfshaven)	10%	20%	1
Niew-Mathensse (Delfshaven)	N.A.	N.A.	N.A.
Nieuwe Werk (Centrum)	2%	14%	1
Nieuwe Westen (Delfshaven)	13%	47%	2
Nesselande (Prins-Alexander)	3%	16%	1
Noordereiland (Feyenoord)	11%	44%	2
Middelland (Delfshaven)	9%	36%	1
Ommoord (Prins-Alexander)	9%	51%	2
Oosterflank (Prins-Alexander)	12%	60%	2
Oude Noorden (Noord)	14%	58%	2
Oude Westen (Centrum)	15%	61%	3
Oud Ijsselmonde (Ijsselmonde)	5%	11%	1
Overschie (Overschie)	6%	23%	1
Pendrecht (Charlois)	15%	55%	3
Prinsenland (Prins-Alexander)	10%	55%	2
Provenierswijk (Noord)	10%	44%	2
Rubroek (Kralingen-Crooswijk)	12%	52%	2
Stadsdriehoek (Centrum)	7%	20%	1
Spangen (Delfshaven)	13%	61%	2
Tarwewijk (Charlois)	12%	34%	1
Tussendijken (Delfshaven)	18%	60%	3
Vreewijk (Feyenoord)	16%	73%	3
Wielewaal (Charlois)	17%	96%	3
Zuidwijk (Charlois	17%	66%	3
Zevenkamp (Prins-Alexander)	11%	46%	2
City average	**11%**	**44%**	

Note: socio-economic data from Onderzoek010. (Onderzoek010, 2021abc)

Appendix 2: Calculated reduction in the MRDH model

The simulated PT frequency level reduction is calculated over all PT-lines in the Metropolitan Region Rotterdam-The Hague (MRDH), as the model is originally designed to execute calculation for this entire metropolitan region. As every PT line has a different frequency for different parts of the day. (rush hour sees a higher frequency then off-peak hours), the daily frequencies are divided into three day parts: Morning rush hour, Afternoon rush hour and off-peak. In table 1, the example for the North-South bus frequency, line 44 (Rotterdam central station – Zuidplein bus terminal), the intervals and hourly frequencies are presented for the three day parts.

Line 44	Morning rush hour	Afternoon rush hour	Off-peak interval
Interval	5	7½	10-20
Hourly frequency	12	8	4-3

Table. X bus frequency intervals for Line 44 in 2019

<u>Bus stop waiting times and transfer waiting times</u>

When a passenger wants to travel by PT, he/she has to arrive at the designated stop first. The average time a passenger has to wait at a random moment during the day, is determined by the frequency of the desired frequency. Therefore the estimated waiting time can be calculated using the following formula:

$$Avg. passenger\ waiting\ time = \sum \frac{1}{4} \cdot \ (60\ /\ hourly\ frequency\ )$$

When a transfer is needed in the travel, the transfer time is calculated in a corresponding manner:

$$Avg. passenger\ transfer\ time\ = \sum \frac{1}{2} \cdot \ (60\ /\ hourly\ frequency\ )$$

These calculations indicate that the decrease of frequencies the ease of connectivity between lines (transfers) will change. The divisional difference can be explained by the simple fact that departure time can be managed by the individual. You can determine at what time you want to leave home to head for the stop. Transfer times, on the other hand, are out of the influence of the passenger and therefore have a larger time margin.

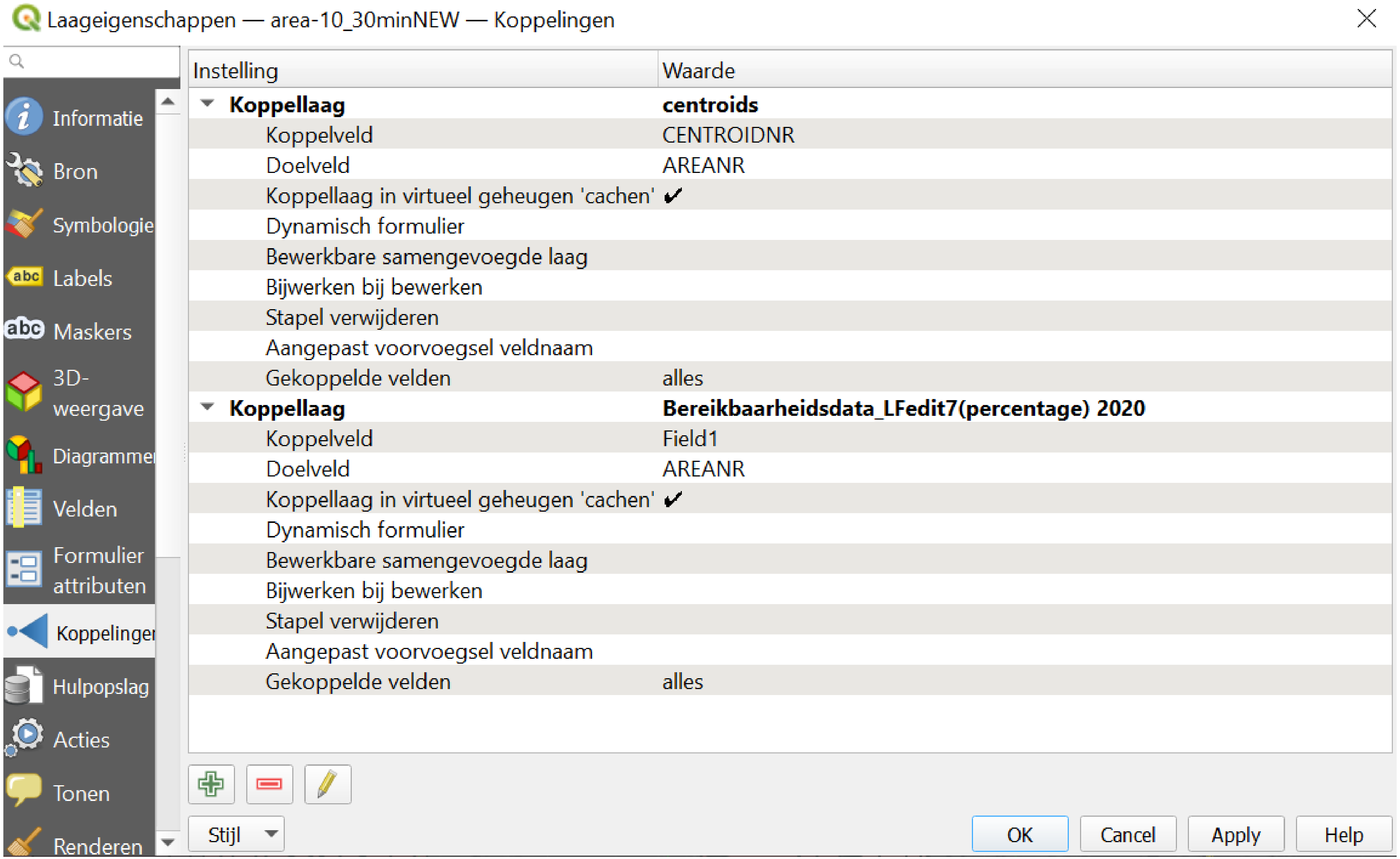
Appendix 3: MRDH calculation outcome example per zone.

The level of *ontplooingsmogelijkheden* indicates the number of jobs accessible per 1000. 2020 is the basis model with TP timetable of 2020. 10p reduction is -10% scenario and 30p =-30% reduction. In total calculations have been made for 1387 zones within the Municipality of Rotterdam. The full excel with all 1387 zones is available upon request.

Vergelijkinsgvarianten	
Var1	2020
Var2	2020_10p_reductie

ABSOLUTE AANTALLEN		Variant: 2020						Variant: 2020_10p_reductie					
Zone		Economische potentie			Ontplooiingsmogelijkheden			Economische potentie			Ontplooiingsmogelijkheden		
CentroidNrs	Centroid	30 min	45 min	60 min	30 min	45 min	60 min	30 min	45 min	60 min	30 min	45 min	60 min
5093	5093: Parkeerlocatie De Loper	109	352	916	42	191	470	103	327	857	38	175	435
5424	5424	216	768	1554	119	357	697	209	744	1507	116	344	666
5477	5477	337	898	1706	182	436	871	328	875	1654	179	422	837
6686	6686: Parkeerlocatie Maastoren	525	1229	2193	253	540	964	511	1191	2110	247	520	918
6676	6676: Parkeerlocatie Plaza/Casino	602	1471	2708	323	763	1458	583	1423	2598	313	733	1400
6237	6237: RTD Charlois	184	549	1120	115	304	568	178	533	1090	108	290	536
6222	6222: RTD Charlois	327	850	1545	156	369	674	319	827	1502	152	358	650
5649	5649: RTD Hillegersberg, Schiebro	264	848	1770	136	408	793	249	802	1701	131	392	761
5779	5779: RTD Kralingen	372	938	1677	172	381	712	360	913	1627	168	370	677
6055	6055: RTD Ijsselmonde	231	669	1228	108	290	496	219	642	1194	103	281	481

Verschillen t.o.v. 2020		Absolute verschillen						Indices					
Zone		Economische potentie			Ontplooiingsmogelijkheden			Economische potentie			Ontplooiingsmogelijkheden		
CentroidNrs	Centroid	30 min	45 min	60 min	30 min	45 min	60 min	30 min	45 min	60 min	30 min	45 min	60 min
5093	5093: Parkeerlocatie De Loper	-6	-25	-59	-4	-16	-35	94,5	92,9	93,6	90,5	91,6	92,6
5424	5424	-7	-24	-47	-3	-13	-31	96,8	96,9	97	97,5	96,4	95,6
5477	5477	-9	-23	-52	-3	-14	-34	97,3	97,4	97	98,4	96,8	96,1
6686	6686: Parkeerlocatie Maastoren	-14	-38	-83	-6	-20	-46	97,3	96,9	96,2	97,6	96,3	95,2
6676	6676: Parkeerlocatie Plaza/Casino	-19	-48	-110	-10	-30	-58	96,8	96,7	95,9	96,9	96,1	96
6237	6237: RTD Charlois	-6	-16	-30	-7	-14	-32	96,7	97,1	97,3	93,9	95,4	94,4
6222	6222: RTD Charlois	-8	-23	-43	-4	-11	-24	97,6	97,3	97,2	97,4	97	96,4
5649	5649: RTD Hillegersberg, Schiebro	-15	-46	-69	-5	-16	-32	94,3	94,6	96,1	96,3	96,1	96
5779	5779: RTD Kralingen	-12	-25	-50	-4	-11	-35	96,8	97,3	97	97,7	97,1	95,1
6055	6055: RTD Ijsselmonde	-12	-27	-34	-5	-9	-15	94,8	96	97,2	95,4	96,9	97


Laageigenschappen — area-10_30minNEW — Koppelingen
Informatie
Bron
Symbologie
Labels
Maskers
3D-weergave
Diagramme
Velden
Formulier attributen
Koppelinger
Hulpopslag
Acties
Tonen
Renderen
Instelling
Waarde
Koppellaag
centroids
Koppelveld
CENTROIDNR
Doelveld
AREANR
Koppellaag in virtueel geheugen 'cachen' ✔
Dynamisch formulier
Bewerkbare samengevoegde laag
Bijwerken bij bewerken
Stapel verwijderen
Aangepast voorvoegsel veldnaam
Gekoppelde velden
alles
Koppellaag
Bereikbaarheidsdata_LFedit7(percentage) 2020
Koppelveld
Field1
Doelveld
AREANR
Koppellaag in virtueel geheugen 'cachen' ✔
Dynamisch formulier
Bewerkbare samengevoegde laag
Bijwerken bij bewerken
Stapel verwijderen
Aangepast voorvoegsel veldnaam
Gekoppelde velden
alles
Stijl
OK
Cancel
Apply
Help