The influence of residential and work locations on commuting durations and distances

Changes in the last decade for different income groups in Amsterdam

Mike Schroten

Delft University of Technology
Wageningen University & Research
MSc. Metropolitan Analysis, Design & Engineering

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by

Mike Schroten

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Thesis Committee:	Prof. dr. B. van Wee	Delft University of Technology
	Dr. K. Maat	Delft University of Technology
	Dr. K. Kujawa	Wageningen University & Research

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Abstract

This study examines the extent of which residential location and workplace location affect commuting duration and commuting distance. Moreover, by splitting to income groups social equity issues in commuting in connection to rising property values in Amsterdam come to the fore. The report employs data from the 2010, 2011, 2016 and 2017 OViN surveys to investigate changes over a time period of five years.

The findings from the spatial analysis, data analysis and regression models indicate that not low income households but instead middle income households more often live less central than high income households. Middle income commuters did not reduce their commuting duration and commuting distance by moving away from the city centre. Both increase when they reside less central. Low income commuters, however, did improve their commute and now commute shorter than middle and high income commuters. When working outside Amsterdam commuters who reside central in Amsterdam but not central outside Amsterdam experience the shortest commutes. People who reside not central outside Amsterdam experience shorter commuters than those who reside central outside Amsterdam.

Given the findings described in this report a new debate could arise in which not the worsening opportunities of low income households should be prioritised, but instead should give way to the worsening conditions of middle income households. Future research should focus on personal preferences of individual commuters. In this research the assumption was made that every respondent that lives in Amsterdam choses to do so. This assumption cannot be made for people living elsewhere, because they may not want to live in a dense urban area. By integrating the personal preferences of respondents the different groups can be better compared.

Preface

This thesis report marks the completion of the master programme "Metropolitan Analysis, Design & Engineering", a joint-degree master of TU Delft and Wageningen University in cooperation with the Amsterdam Institute for Advanced Metropolitan Solutions. During the master programme students are encouraged to come up with creative solutions for urban sustainability issues, and in the last four years a big variety of urban challenges and solutions have been discussed.

For my master thesis I decided to research study to what extent peoples' residential location and workplace location affect commuting duration and commuting distance. An increasing amount of urban dwellers can no longer afford living in urban areas, affecting their quality of life. Moreover, because people have to reside elsewhere other issues such as reducing air and noise pollution caused by traffic may be harder to combat. This makes the topic very relevant as input for dealing with many urban challenges.

At this point I would like to thank my supervisors Prof. Bert van Wee and Dr. Kees Maat. You inspired me with your knowledge, and encouraged me to think critically and learn new skills. Your guidance in combination with continuous patience have led to the finalisation of this master thesis, for which I am very grateful.

I would also like to thank my family and dearest friends who have supported my throughout the process of writing this report. You have motivated me, but you have also been a welcomed distraction from my thesis.

Enjoy reading this report!

Mike Schroten.
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Summary

Living in city centres becomes more popular, as people value the diversity of cultures and proximity of recreational opportunities (Tordoir, Poorthuis & Renooy, 2015; Hekwolter of Hekhuis, Nijskens & Heeringa, 2017), growing job opportunities (sedghi, 2015) and the high quality of the multi-modal transportation system (Synchroon, 2018). Because of the influx of people property values are rising. High income households can afford these higher prices. Contrarily, low and middle income households struggle to afford living in urban centres. A growing amount of households express that they can no longer buy or rent appropriate housing and as a result have to seek housing at the urban fringe or in nearby suburban communities (VPRO Tegenlicht, 2017). Here, a discussion on social equity comes to the fore. When both high income households and high-skilled jobs relocate to urban centres then this will have a positive impact on accessibility. On the contrary, when low and middle income households forcefully move away from urban centres then their commute likely lengthens.

The problem extends not only to big metropolises such as London and New York, but also to cities of smaller sizes worldwide. In these cities a mix of new residents, expats, investors and tourists put pressure on the housing market (UBS, 2018; European Commission, n.d.). In the Netherlands the phenomenon initiated since the beginning of the 21st century. Here, Amsterdam is an often-used example used by local media (Khaddari, 2020; Couzy, 2020), national media (VPRO Tegenlicht, 2017; nu.nl, 2017; Van den Eerenbeemt, 2017a; 2017b; Remie, 2016) and academics (Raets, 2005) to debate the issue. Critics (VPRO Tegenlicht, 2017; Nu.nl, 2017; Raets, 2005) argue that lower and middle income households are forced to seek residency in Amsterdam's (semi-) peripheral neighbourhoods (e.g. Amsterdam-Zuidoost) or in one of the nearby suburbs (e.g. Almere) because house prices are lower in these communities compared to more centrally located neighbourhoods in Amsterdam.

This research studies to what extent peoples' residential location and workplace location affect commuting duration and commuting distance. Moreover, by splitting to income groups social equity issues in commuting behaviour in connection to rising costs of housing in metropolitan centres, specifically the Metropolitan Region of Amsterdam, come to the fore. If this is the case it could justify intervening in the housing market by the government, such as the Municipality of Amsterdam. The conceptual framework shows that commuting duration and commuting distance are the result of the interaction between someone's residential location and workplace location (Zhao, Bentlage & Thierstein, 2016). Moreover, commuting duration and commuting distance are influenced by the mode of transport selected for travelling between the two locations (Liu, Gao, Ni & Ye, 2020), in which a substantial amount of socio-demographic variables and spatial variables and peoples' personal preferences influence commuting behaviour. Individual decision makers are social influencers and are decisions based on socio-demographic and employment variables. Socio-demographic variables in commuting behaviour are age, gender, household composition and the existence of children (Axisa, Scott & Newbold, 2012). Moreover variables such as education, income, the amount of hours worked per week and people's function in a company affect peoples' commuting behaviour as well (Zhao et al., 2016; Ye & Titheridge, 2016). The spatial context refers to the built environment and is affected by three main variables: land/property values, the distribution of jobs and housing, and the transport network of the urban area (Zhao et al., 2016). These relate to where households are able to afford to live, where

different types of jobs are located and how the transport system enables workers to commute from home to work by a certain mode of transport (Van Wee, 2011; Östh & Lindgren, 2012; Mårtensson, 2015; Zhao et al., 2016; Remie, 2016; Ye & Titheridge, 2016). Personal preferences help to explain why individuals make different decisions based on their background, opinion on certain subjects and the experiences they have had in the past (Horner, 2004; Van der Laan et al., 1998). As a result commuting is often a strategic mobility choice for households rather than a short-term solution (Sandow & Westin, 2010), of which the routine behaviour is only disrupted by external stimuli (Schroten, Otten, 't Hoen, Van Essen, De Wilde, Uyterlinde, Wilmink & Cuelenaere, 2014). As a result, people who live in different areas are fundamentally different to each other. In this research the assumption is made that all people who reside in Amsterdam actively decided to do so. It is not possible to make the same assumption for people who reside outside Amsterdam but who work in Amsterdam. There is a high probability that there are both people who cannot find adequate housing in Amsterdam as well as people who choose to live outside Amsterdam.

Spatial analyses, data analyses and regression analyses are employed to evaluate the extent of how changes in residential and work locations have influenced commuting durations and distances in Amsterdam. In order to do so this study uses data from the OViN[1] surveys of 2010, 2011, 2016 and 2017. By comparing the 2010 and 2011 datasets to the 2016 and 2017 datasets it is possible to describe and explain changes over a time period of five years. The intercity stations (IC stations) of the Netherlands indicate whether someone resides or works centrally. Here, centrality is calculated in kilometres between the residential locations or workplace location to either Amsterdam CS or the nearest IC station.

A fundamental question this thesis examined is whether the commute of low income groups has lengthened as a result of rising property values. Both the mean commuting duration and mean commuting distance increased. This research found no evidence that low income households experience longer commutes because of higher property values. This research, however, did find evidence that middle income households now reside less central. Moreover, middle income households experience longer and farther commutes compared to low and high income households. This implies that middle income households are negatively impacted by residing less central.

In Amsterdam the mean distance between the residential location and the city centre decreased from 7.33 kilometres to 6.78 kilometres. Conversely, the mean distance increased from 6.13 kilometres to 6.44 kilometres for high income households. For middle income households the mean distance between the residential location and Amsterdam CS increased from 6.80 kilometres to 7.20 kilometres, meaning that they reside the least central. In 2010/2011 people who reside in Amsterdam had a shorter commuting duration and commuting distance when they resided farther away from the city centre. However, in 2016/2017 peoples' commute is shorter when they reside closer to the city centre. Working farther away from the nearest intercity station leads to a longer commute.
The regression models also show that the commute of high income households have gotten longer. Low income households have improved their commuting duration and commuting

[1] "Onderzoek Verplaatsingen in Nederland", the largest Dutch annual mobility survey conducted by CBS.

distance in comparison to middle and high income households. Middle income households saw their commute improve in comparison to high income households, but still have the longest commutes. When examining the interaction between peoples' residential and workplace location centrality and their income then it becomes apparent that when low income households reside farther away from Amsterdam CS then their commuting duration and distance increases more than for high income households. The same is true for middle income households, whose commuting duration and commuting distance increases more than for low and high income households when they reside farther away from Amsterdam CS. High income households commute farther in 2016/2017 than in 2010/2011, but because in 2016/2017 they reside more central the larger distance does not impact their commuting duration.

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1. Introduction

1.1 Problem description

Since the turn of the century living in city centres has become more popular. Especially young adults value living centrally due to the diversity of cultures and proximity of recreational opportunities that cannot be found in suburban areas (Tordoir, Poorthuis & Renooy., 2015; Hekwolter of Hekhuis, Nijskens & Heeringa, 2017). Besides cultural and social reasons young adults are also attracted to live centrally because of growing job opportunities. According to British research high-skilled occupations located in large cities (250,000-500,000 inhabitants) have tripled over the last decade (Sedghi, 2015), a bigger increase than in other smaller agglomerations. Moreover, a high quality and multi-modal transportation systems makes getting around convenient (Synchroon, 2018). Because of the influx of people property values are rising. High income households can afford these higher prices. Contrarily, low and middle income households struggle to afford living in urban centres. As a result the housing market is under pressure in many metropolises (Raets, 2005; European Commission, n.d.). An increasing number of households express that they can no longer buy or rent appropriate housing and as a result have to seek housing at the urban fringe or in nearby suburban communities (VPRO Tegenlicht, 2017). The same is true for companies. Big (international) companies can afford to be located centrally whereas smaller companies have to relocate to less central neighbourhoods.

Living and/or working in urban centres has advantages because these areas are often well-connected to the transport system (synchroon, 2018). People can therefore travel quicker and more comfortable than people who live and/or work farther away from urban centres. When both high income households and high-skilled jobs relocate to urban centres then this will have a positive impact on accessibility. On the contrary, when low and middle income households forcefully move away from urban centres then their commute likely lengthens.

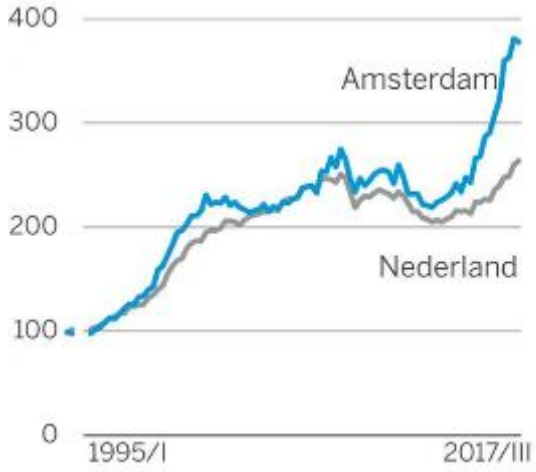
Here, a discussion on social equity comes to the fore. Social equity, the assurance that all communities are treated in a fair manner and are given equal opportunity to participate in the planning and decision-making process, often emphasises on ensuring that traditionally disadvantaged groups (such as low-income households) are not left behind (Sandag, n.d.). When lower and middle-income households are forced to seek housing in less centrally located neighbourhoods then it is arguable that their lives are negatively impacted due to, amongst others, longer commutes. Therefore pushing these people to the urban fringe can reduce their quality of life, whereas high-income households can experience a higher quality of life because they have the financial resources to live in centrally located neighbourhoods.

To conclude, it can be assumed that high income groups that more often live and work in accessible urban centres, either have a short commute time, or at least an efficient home-work trip between urban centres. On the contrary, middle and lower income groups are forced to settle on the urban fringes, increasing their commuting distance and commuting duration. If this is the case it could justify intervening in the housing market by governments. This research investigates if commuting times and commuting durations have changed for different social groups. By taking a larger city as case study area the extent that residential and workplace locations change, and the effect on peoples' commutes, becomes apparent.

The problem extends not only to big metropolises such as London and New York, but also to cities of smaller sizes worldwide. In these cities a mix of new residents, expats, investors and tourists put pressure on the housing market (UBS, 2018; European Commission, n.d.). In the Netherlands the phenomenon initiated since the beginning of the 21st century. Here, Amsterdam is an often-used example used by local media (Khaddari, 2020; Couzy, 2020), national media (VPRO Tegenlicht, 2017; nu.nl, 2017; Van den Eerenbeemt, 2017a; 2017b; Remie, 2016) and academics (Raets, 2005) to debate the issue. Amsterdam experiences an influx of people that are attractedby the opportunities that the city has to offer. Moreover, as in metropolises worldwide more high-skilled job opportunities relocate to Amsterdam (De Jong, Van Oosteren & Slot, 2018; Van Zoelen, 2018). As a result owner-occupied house values have risen above the Dutch average since 2013 (Van den Eerenbeemt, 2017). Moreover, waiting times for social housing have lengthened and households that rent property have to pay more as well (Dirks, 2017). Simultaneously the small housing stock of affordable houses (e.g. social housing or owner-occupied housing meant for young adults that are new on the housing market) is shrinking, while even the housing stock in the intermediate segment decreases at the cost of growth in the expensive housing segment (Berkers & Dignum, 2018; Savini et al., 2015). As a result lower and middle income households are forced to seek residency in Amsterdam's (semi-) peripheral neighbourhoods (e.g. Amsterdam-Zuidoost) or in one of the nearby suburbs (e.g. Almere) because house prices are lower in these communities compared to more centrally located neighbourhoods in Amsterdam (VPRO Tegenlicht, 2017; Nu.nl, 2017; Raets, 2005). At the same time high income households that live centrally can commute efficiently to their jobs.

Figure 1.1

Change in house prices (x1000) in Amsterdam and the Netherlands (Van den Eerenbeemt, 2017b).



Note: 1995 = index 100.

Most studies on commuting patterns have shown that people with a higher income -often relating to a higher educational background- usually experience longer commuting durations than those with a lower income. Commuting patterns around Amsterdam can shift due to an increase in high-skilled jobs in central areas (CBS, 2016; Olde Kalter, Bakker & Jorritsma, 2010; Van Wee, Annema & Banister, 2013; De Jong et al., 2013).

1.2 Research gap

Commuting is the activity of travelling a distance between home and work on a regular basis, and is therefore undergone by all employed persons that have a fixed workplace outside of their homes (Filipi, 2014). Historically the spatial distance between people's residential location and work location were closer attached. Nowadays people have been enabled to live further away from their workplace due to ever-improving transport opportunities as well as by improvements of infrastructural systems (Östh & Lindgren, 2012). Commuters can therefore overcome greater distances. Because recent studies show that both commuting distances and durations are still increasing it is uncertain whether this is also true when moving to a bigger agglomeration.

Reports on commuting behaviour are published annually by many national statistics bureaus throughout Europe. These reports are used to monitor changes in peoples' travel behaviour. Additionally, academics regularly publish about commuting behaviour and the way it influences peoples' lives. As a result we know that commuting times and distances are still lengthening (Mårtensson, 2015). For example, in Britain research suggests that commuting times have lengthened from 24 minutes to 30 minutes over the last 20 years (Chatterjee, Clark, Martin & Davis, 2017). In the Netherlands commuting distances have increased from 14.8 kilometres to 18.5 kilometres between 1995 and 2016 (Ritsema van Eck & Hilbers, 2018). Measures such as improvements on the transport system could increase travel speeds and as a result commuting durations may stay the same when commuting distances prolong (Mårtensson, 2015).

By studying on a national level it is difficult to conclude whether the same is the case for cities such as Amsterdam because people's residential locations are may be different and undergoing big changes and more jobs for higher educated employees move towards central areas (Hekwolter of Hekhuis et al., 2017; Tordoir et al., 2015). Tordoir et al. (2015) mention that urban areas undergo different developments than other areas. Hekwolter of Hekhuis et al. (2017) argue that researching on a national level may give different outcomes than when only one urban area is studied.

Taking into account all the non-scientific articles, it is surprising that hardly any scientific literature exists about rising property values and the impact on low and middle income groups. This is especially true when authors have written about the differences between areas of a different urbanisation level. Limited literature can be found that describes how commuting patterns develop on a regional or local spatial level. British research found that people are not likely to move houses in order to decrease their commuting time (Mason, 2005). Moreover, Lyons & Chatterjee (2008) and Hekwolter of Hekhuis et al. (2017) suggest that other factors influence people's tendency to move houses or change jobs in order to improve the commuting time. Examples given are people's social network and the costs and quality of living. This suggests that rising house prices in metropolitan areas do in fact influence people's commuting time because they have to live elsewhere, probably farther away from their work location.

In the last 20 years the availability of jobs for higher educated people increased in (central) urban areas, relocating from suburban areas (Tordoir et al., 2015). Ritsema van Eck & Hilbers (2018) found that in the last 20 years the share of people holding a higher education degree increased as well. While Van Wee (2011) states that people holding a higher education degree more often have to travel greater distances to reach a suitable job, it is uncertain if a higher availability of suitable

jobs decreases the need for commuting bigger distances. This is especially doubtful if the amount of people holding a higher education degree increases as well. Ritsema van Eck & Hilbers (2018) primarily focus on studying changes in commuting patterns at a higher geographical scale than one urban area. Reports focusing on a local scale (e.g. the Municipality of Amsterdam (2017)) do mention a possible relation between the location where people live and where they work, but the impact on travel patterns has not been explored. Therefore it is relevant to study how people's (changing) residential and work locations affect commuting times and distances in Amsterdam. As a result this thesis research does not emphasise on the willingness to travel for a certain job, but much more takes on people's residential and work locations as a starting point.

1.3 Objectives & research question

This study describes to what extent residential and work locations of different income groups living and/or working in Amsterdam have changed over the last decade. By doing so the influence of these locations on commuting times and distances are explained. As a result it is possible to examine whether the changes in residential and work locations have had positive or negative consequences for different income groups. This thesis therefore adds to the knowledge on changing residential and work locations and its impact on commuting times and distances in urban areas. By researching different income groups the objective of this thesis research is to contribute to social equity, by explaining the impact of residential and work locations on commuting times and distances for different income groups.

Amsterdam represents a bigger agglomeration where both resident and work locations have relocated in the last decades. Moreover, a relatively high share of households in the city are identified as low-income households. It is possible that a higher share of citizens is therefore impacted by changing residential and workplace locations. Because the phenomenon of rising property values

This study is guided by the research question to what extent different income groups are impacted by changes in residential and workplace locations and as a result commuting durations and distances over the last decade in Amsterdam.

The conceptual framework presented on page 22 shows that commuting is established by the residential location, workplace location and the used mode of transport. Many factors influence these locations and the selected mode of transport. These can be categorised into individual decision makers and the spatial context (Zhao, Bentlage & Thierstein, 2016). Decision makers entail information about the household member, his/her employment conditions. Moreover, various researchers have shown that few people are willing to move houses solely to decrease their commuting duration (Mason, 2005; Lyons & Chatterjee, 2008; Hekwolter of Hekhuis et al., 2017). Therefore more factors affect the decision of where to reside and work, There individual preferences are also embedded in the individual decision makers box. The spatial context relates to land/property prices, the quality of transport networks and the distribution of jobs and housing (and service) facilities.

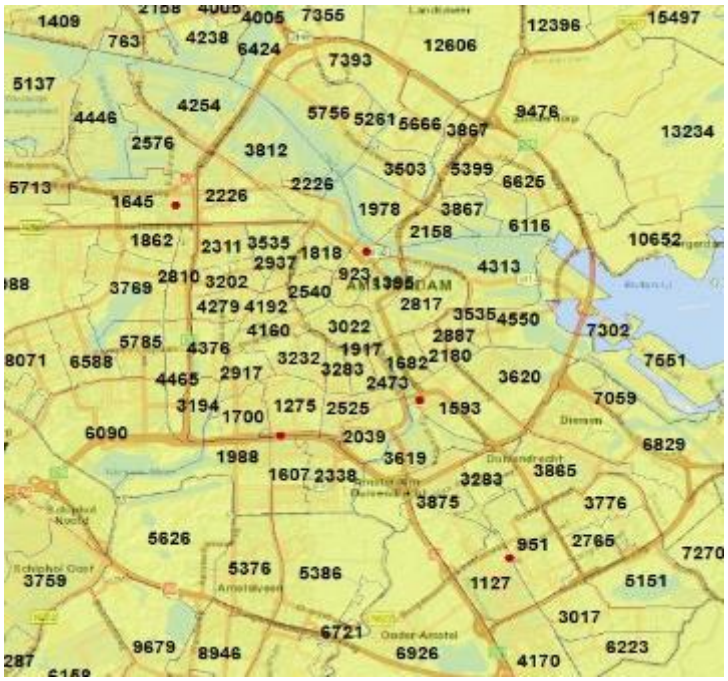
1.4 Approach

The data required to analyse the commuter journeys is derived from the OViN survey, which is the largest national mobility survey of the Netherlands conducted annually by CBS. The OViN datasets of 2010, 2011, 2016 and 2017 are used so that developments over a five-year timespan will be analysed. The lowest spatial level in the datasets is represented by 4-digit postal codes (figure 1.2). Because new samples are taken from the total population each year it is not possible to perform a longitudinal research, meaning that this data is repeated cross-section data (Van de Coevering, 2012). Herewith changes the sample group's residential and workplace location are describe for 2010/2011 and 2016/2017. Moreover, by splitting to income differences between social groups can be described. Other factors such as mode of transport, age, family composition and gender will be used as controlling factors to verify the influence of income on commuter journeys as they also influence people's commuting patterns (Van Middelkoop & Schilder, 2017; CROW, 2016; Van Wee et al., 2013). In order to compare residential and work locations the distance of the postal zone to the nearest intercity railway station (IC station) is calculated. These railway stations have been chosen because of their central positions in urban areas (synchroon, n.d.).

This study analyses whether or not there is a connection between people's commuting times and their residential and work location. Hence a regression analysis will be proposed. More specific, an ordinary least squares method will be applied because the dependent variables are continuous variables. Commuting duration and commuting distance will be the dependent variable (y) of separate regression models, while the independent variables (x) are residential location centrality and workplace location centrality. Age, gender, household composition, household income, highest completed education & main mode of transport are also included as independent variables.

Figure 1.2

Example of 4-digit postal zones compared to the nearest intercity station (red dots).



1.5 Readers' guide

Chapter 2 provides an overview of the literature on commuting behaviour and influences of commuting behaviour, followed by the conceptual framework. The methodology is presented in chapter 3, in which the case study area, datasets, research method and data processing are described. The results section of this report are divided into two chapters. First, chapter 4 focusses on the data characteristics. Here, the spatial and data analyses are described and explained. Consequently, chapter 5 describes and explains the regression models. Thereafter the conclusions, discussions and recommendations are presented in chapter 6.

2. Literature review

Many researchers have written extensively about commuting patterns and commuting behaviour. For this literature review ScienceDirect was used to retrieve scientific literature on the broad concept of commuting in a structural manner. The scope was to research which factors influence peoples' commute. These factor can both be related to the (social) background of an individual, as well as external factors. Section 2.1 provides an introduction into the concept of commuting. Section 2.2 investigates which factors are influencing peoples' commutes. Thereafter, the way that peoples' commuting pattern can alter is described in Section 2.3. The conceptual framework of this thesis can be found in Section 2.4.

2.1 Definition of and trends in commuting

Commuting is the activity of travelling a distance between home and work regularly (Zhao et al., 2016). It is undergone by all persons that have their workplace outside of their homes (Filipi, 2014). Therefore employees that work from home are left out of most studies on commuting patterns, amongst others because the growing share of people working from home otherwise counteracts trends of the people that have a workplace outside of their home (Chatterjee et al., 2017). Many national governments publish annual reports on commuting patterns of their citizens. Moreover, academics not only research developments in commuting patterns overtime, but also discuss the implications of these changes.

Historically the spatial distance between people's residential location and work location was closer attached. However, nowadays people have been enabled to live further away from their workplace due to faster transportation options and improved infrastructural systems (Östh & Lindgren, 2012). Commuters can therefore overcome greater distances without increasing travel times. However, recent studies have shown that both commuting distances and commuting durations are increasing (Mårtensson, 2015). In Canada the median commute distance increased nearly 8.5%, while at the same time the average commute duration (of a round trip) increased from 54 minutes in 1992 to 63 minutes in 2005 (Statistics Canada, 2006; Statistics Canada, 2007). More recent British research suggests that commuting times have lengthened from 24 minutes to 30 minutes over the last 20 years (Chatterjee et al., 2017), and in the Netherlands commuting distances have increased from 14.8 kilometres in 1995 to 18.5 kilometres in 2016 (Ritsema van Eck & Hilbers, 2018).

2.2 Factors that influence commuting

The existing commuting literature uses many variables to better understand commuting behaviour, and numerous variables have been tested over the years with different degrees of success (Axisa et al., 2012). These variables can be divided into social and spatial factors (Zhao et al., 2016).

Regarding social factors, many researchers use socio-demographics such as age, gender, household composition, marital status and the existence of children. Of these variables, gender is the most utilised and most consistent variable in relation to commuting behaviour (Axisa et al., 2012). Studies such as Clark, Huang & Withers(2003) have consistently found that males

experience longer commutes than females. Suggested is that one parent, more often the female, will decrease their amount of paid work hours, commuting distance and commuting time in order to cope with domestic responsibilities and child care (Clark et al., 2003). When considering households specifically Clark et al. (2003) indicate that commuting patterns of one-worker and two-worker households are alike. According to Möhlmann, Weijschede-Van der Straaten & Rouwendal (2013) two-worker households are more willing to spend on good accessibility of their residential location than single-person households. Here, a compromise is often found which increases the commuting duration and commuting distance of one worker, while for the other worker commuting duration and commuting distance improves. By doing so the overall situation improves. Alternatively, when an individual ceases to live together with a partner then their commuting time is reduced, most probably because the person moves closer to their workplace location (Dargay & Van Ommeren, 2005). This is also true for single parents, suggesting that they either move closer to the workplace or make use of faster transportation in order to be able to spend more time with their child(ren) (Dargay & Van Ommeren, 2005). On the other hand, when one parent stays at home then the other adult often has a longer than average commutes (Axisa et al., 2012). Additionally, as the age of the youngest child decreases, commuting distances increase. Axisa et al. (2012) argue this reflects the preference of parents to raise their children in suburban environments.

Axisa et al. (2012) and Champion, Coombes & Brown (2008) state that middle-aged workers have the longest commutes. Here, Axisa et al. (2012) found that people aged 30 to 44 have the longest commuting distances. Ritsema van Eck & Hilbers (2018) show that people who work part time choose to have a shorter commuting duration and commuting distance than people who work full time. On average workers spend 10.5% of the time available for work on commuting, corresponding to 28 minutes (one way) for an eight hour workday (Schwanen & Dijst, 2002). Therefore people that take care of the household -more often being the female- decrease the amount of working hours, hence reducing their commuting distance and commuting duration.

Commuting behaviour associates strong ties between residential location decisions and employment (Axisa et al., 2012). People holding a higher education degree often require a more specialised job and therefore have to travel farther in order to reach a suitable job (Van Wee, 2011). As mentioned previously, households are often more willing to pay for a better accessible residential location. Taking into account education, it seems that higher educated households are more willing to pay for a residential location that is better accessible compared to lower educated households (Möhlmann et al., 2013). Green (1999) argues that urban residents have shorter commute times than rural residents, because most rural areas lack specialised (high-skilled) jobs. Consequently, rural residents seek employment in larger labour markets near urban areas, while preferring to reside in less expensive areas or in towns that provide the rural ideals (Green, 1999).

Household income is affected by other variables before affecting commuting behaviour. For example, spending more time at home to take care of a child means that the individual will work less hours resulting in a lower income. Moreover, it is beneficial to consider other environmental influencers as well (Johnston, 2019). Johnston (2019) found that there is a statistically significant positive correlation between commuting duration and household income. Van den Berg & Gorter (2012) suggest this is most probably caused by the willingness to pay for commuting time. In the Netherlands the average willingness to pay for commuting one hour is about half the hourly wage (Van Ommeren, Van den Berg & Gorter, 2002) Moreover, Dargay & Van Ommeren (2005) state

that a small positive income elasticity exists between income and commuting time where a 10% increase in income leads to an increase in commuting time by 0.4%. Here, the individual did not change residential location or workplace location.

The spatial context therefore has its own way of influencing commuting behaviour (Jun, 2020). It is believed that the built environment fundamentally influences commuting patterns and can pose various urban issues such as congestion, noise and air pollution and both mental and physical health problems (Jun, 2020). In the previous century urban growth patterns have shown substantial suburbanisation and decentralisation, making the urban structure an interesting research topic (Anas, Arnott & Small., 1998). Here, variables such as the design of neighbourhoods, density, diversity and the transport system have been utilised for many different trip purposes (Jun, 2020). Zhao et al. (2016) argue that regarding commuting spatial context factors such as the transportation network, land/property prices and the distribution of jobs & housing (relating to density and diversity) are primary factors that influence peoples' residential and workplace locations.

Different opinions exist about the influence of the size of an urban area on commuting patterns. While American research (Gordon, Kumar & Richardson, 1989) suggests that the size of urban areas has little effect on commute duration and commute distance, European research shows evidence that the average commute duration or distance rises when urban areas are larger (Coombs & Raybould, 2001; Schwanen, 2002). Schwanen, Dieleman & Dijst (2004) argue that this appears reasonable as the maximum possible commute duration and commute distance increases. Östh & Lindgren (2012) found that improvements on the transportation system enabled people to live farther away from their workplace location, making the spatial distance between residential location and workplace location less important. These improvements should not be limited to infrastructural improvements, but should also focus on the efficiency and connectivity of the network. For public transportation it means that vehicles should drive on a high frequency rather than once or twice an hour (Östh & Lindgren, 2012). For slower modes of transport such a bicycles it could mean prioritisation when passing by traffic lights.

Examining the jobs and housing distribution to study commuting behaviour (as proposed by Zhao et al., 2016) can be more relevant than looking solely at the size of an urban area. First, many urban planners and researchers propose that the "jobs-housing balance", the number of jobs in an urban area in relation to the labour force, fundamentally determines commuting behaviour (Schwanen et al., 2004; Shen, 2007). For example, if the number of jobs in an area is low the people living in that area may find it more difficult to find a suitable job, possibly resulting in a longer commute duration and commute distance (Levinson, 1998). In the Dutch context the sizes of urban areas are relatively small, making it more feasible for commuters to travel between them (Schwanen et al., 2004). Secondly, because peoples' residential location is not only affected by the location of their job it is important to note that competition exists for obtaining suitable housing. In many car-dependent nations this phenomenon has been described as drive until you can afford (Kellett, Morrissey & Karuppannan, 2016), describing that urban centres are attractive and therefore more expensive to live. As a result, middle and low-income households have to find suitable housing at the urban fringe. They will as a result have to travel bigger distances in order to reach destinations. Land/property prices are therefore a noteworthy variable when explaining the influence of the spatial context on residential and workplace location (Zhao et al., 2016).

Again, however, it is important to note that differences between similar urban areas exist and therefore other spatial and social factors must be taken into account as well (Jun, 2002).

Despite the large amount of literature on the relationship between commuting behaviour and the urban form the general debate remains inconclusive. Jun (2020) proposes several reasons for the inconclusiveness of the empirical findings. First, the association between urban form and commuting patterns are highly intercorrelated by various variables such as a city's historical, political and socioeconomic situation, transportation system and regulation. Secondly, the fact that both spatial and social factors influence someone's commuting behaviour result in substantial differences amongst cities of similar size and distribution of jobs and housing (Jun, 2020).

Having said this, it is important to note the importance of peoples' personal preferences for making decisions on their residential location, workplace location and commuting behaviour (Zhao et al., 2016). Peoples' British research found that people are not likely to move houses in order to decrease their commuting time, because other factors influence peoples' tendency to move houses or change jobs in order to improve the commuting time (Mason, 2005; Lyons & Chatterjee, 2008; Hekwolter of Hekhuis et al., 2017). Since the turn of the century living in city centres have become more popular as especially young adults value living centrally due to the diversity of cultures and proximity of recreational opportunities (Tordoir et al., 2015; Hekwolter of Hekhuis et al., 2017). At the same time other people value living in more rural areas (Green, 1999). It means that people who live in different areas are fundamentally different to each other because of their personal preferences. Therefore people that live at one place cannot be compared to people living at another place without knowing why they chose to live there. People who reside in urban centres more likely actively decided to do so. It is not possible to make the same assumption for people who reside outside urban centres (but do work there). There is a high probability that there are both people who cannot find adequate housing in an urban centre as well as people who choose to live in e.g. a less dense neighbourhood.

Life events such as the birth of a child mean that households are more likely to change their residential location or workplace location (Remie, 2016), for example because moving to a bigger house is necessary (Van Middelkoop & Schilder, 2017). As a result young adults are more likely to move houses than seniors and families. Moreover, changing someone's workplace location will make households reconsider their commuting behaviour, and for some their residential location when the distance between home and work becomes too big (Van Middelkoop & Schilder, 2017).

If certain residential areas get more attractive, then property prices will increase (Hekwolter of Hekhuis et al., 2017; Tordoir et al., 2015. As a result people that have a lower income cannot afford to move to a certain neighbourhood. Papers that debate the connection between household income and their moving behaviour are contradictory. Balgova (2018) and Greenwood (2018) found that low income households less frequently move houses than high income households because their budget for housing is limited. On the other hand Phinney (2013) states that low income households move more often as a result of involuntary transitions. Though little research has been conducted in the Netherlands some researchers (VPRO Tegenlicht, 2017; Raets, 2005) found that low income households more often live at the urban fringe of Amsterdam due to lower property prices as the ongoing migration towards the city is the primary driver for rising property prices (Hekwolter of Hekhuis et al., 2017). In particular highly educated and young people are

drawn to urban centres because of its variety in culture, institutions and recreation. Moreover, centrally located urban regions attract new jobs for those that hold a higher education degree, and is another driver for migration towards the city (Tordoir et al., 2015).

2.3 Changing commuting behaviour

According to Schroten et al. (2014) three types of behaviours exist. Firstly, routine behaviour are decisions that are made daily and (almost) automatically, such as when driving a car. Secondly, conscious behaviour includes decisions such as taking a different route to work. In mobility this often means a disruption of the routine behaviour. Thirdly, "one-shot" behaviour is the type of behaviour of which an individual is most conscious, and includes decisions such as moving houses or buying a new car. Gardner (2009) notes that peoples' daily commute is repeated with little or no conscious consideration of alternatives. This means that for most individuals commuting is part of their routine behaviour (Schroten et al., 2014). As a result it is challenging to change peoples' commuting behaviour, even if the quality of other modes of transport (such as public transport) are improved (Clark, Chatterjee & Melia, 2016), and often only changes when routine behaviour is disrupted (Schroten et al., 2014).

Here, the habit-discontinuity hypothesis posits that routine behaviour can be altered by (external) disruptions (Verplanken, Walker, Davis & Jurasek, 2008). The biggest disruption in commuting behaviour is when the distance between peoples' residential location and workplace location changes because of moving houses or when changing jobs (Clark et al., 2016), because both routine behaviour decisions and conscious behaviour decisions are disrupted (Schroten et al., 2016; Verplanken et al., 2008). Panter, Griffin, Dalton & Ogilvie (2013) found that other disruptions have personal, household and spatial characteristics and can be both objective and subjective. For example, Panter et al. (2013) indicate that walking to work is associated with not having children, most likely because workers want to spend more time with their child(ren) than on commuting. Other examples are separation from a partner (Oakil, Ettema, Arentze & Timmermans, 2011) and changes in transport costs (Ben-Elia and Ettema, 2011).

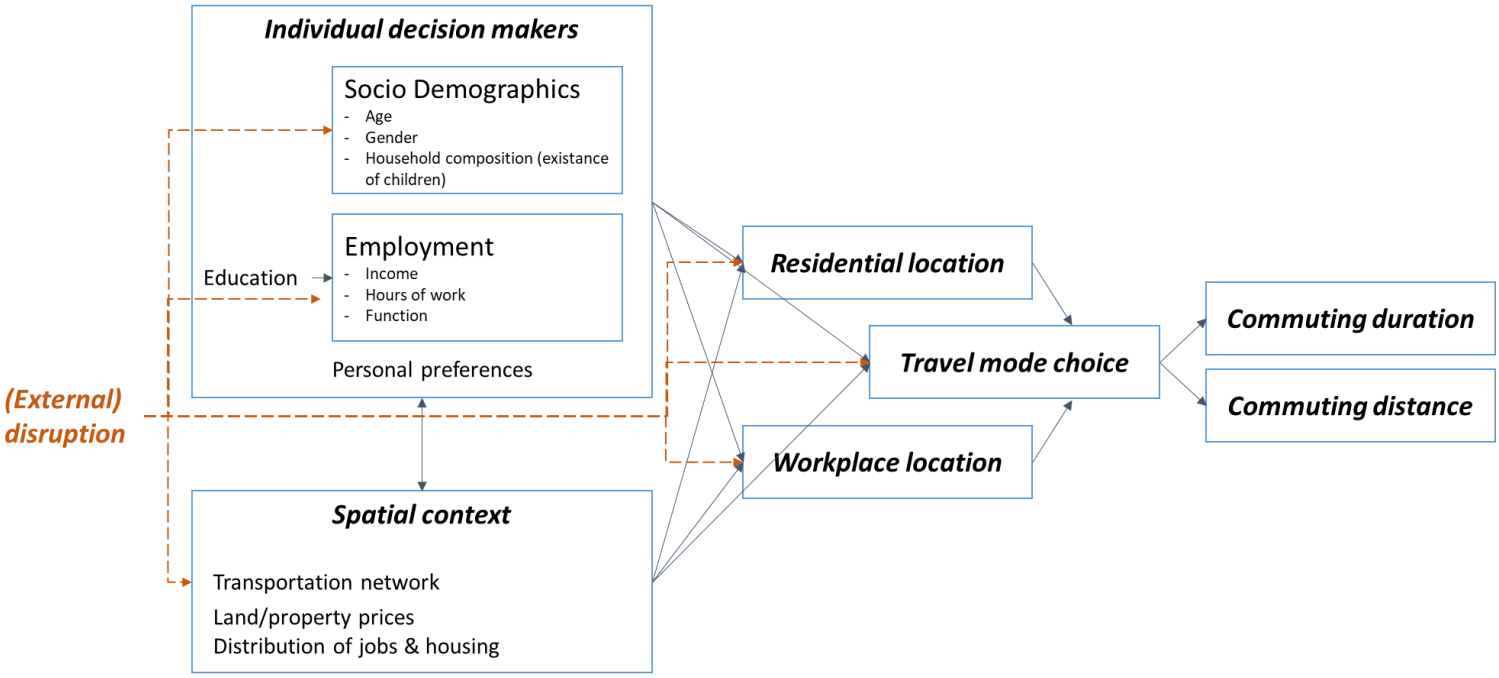
Examples that are caused by external disruptions exist as well. Heinen, Panter, Mackett & Ogilvie (2015) mention that improving the public transport system has led to commuters switching to other modes of transportation. Marketing interventions such as free public transport passes encourage travellers to change the way they commute (Thørgersen, 2006). According to Clark et al. (2006) these initiatives more likely have an effect when they are applied to commuters that experience life events, as in such case multiple disruptions occur simultaneously.

2.4 Conceptual framework

This Section presents a conceptual framework (figure 2.1) that is built around the research topic "commuting" and is based on the literature that has been explained in Section 2.1.

Figure 2.1

Conceptual framework on commuting.



Peoples' commuting duration and commuting distance are a result of the interaction between someone's residential location and workplace location. Commuting duration and commuting distance are influenced by the mode of transport selected for travelling between the two locations. The substantial amount of factors that influence peoples' residential location, workplace location and choice of mode of transport are divided into individual decision makers and the spatial context (Qing, 2007; Zhao et al., 2016; Ye & Titheridge, 2016).

Individual decision makers are social influencers and are decisions based on socio-demographic and employment variables. Socio-demographic variables such as age, gender, household composition and the existence of children (Axisa et al., 2012). Employment variables are income, the amount of hours worked per week and people's function in a company (Zhao et al., 2016; Ye & Titheridge, 2016). Here, education is acknowledged to influence employment, because certain educations require a more specialised job than others (Van Wee, 2011).

The spatial context refers to the built environment and is affected by three main variables: land/property values, the distribution of jobs and housing, and the transport network of the urban area (Zhao et al., 2016). These relate to where households are able to afford to live, where different types of jobs are located and how workers are enabled to commute from home to work by a certain mode of transport (Van Wee, 2011; Östh & Lindgren, 2012; Mårtensson, 2015; Zhao et al., 2016; Remie, 2016; Ye & Titheridge, 2016). When the transport system is improved or public transport drives more frequently commuters may not travel longer when they decide to move farther away from the workplace. Therefore commuting duration and commuting distance are related to each other, which is why the analyses in this research are made for both commuting duration and commuting distance separately.

Personal preferences help to explain why people have different opinions on the attractiveness of certain urban forms. Someone's workplace location does not fully determine their residential location (Horner, 2004; Van der Laan et al., 1998). It is why people do not move elsewhere when they change jobs (Mason, 2005). As a result commuting is often a strategic mobility choice for households rather than a short-term solution, which is why commuting behaviour most likely changes when external disruptions or life events take place (Clark et al., 2016; Schroten et al., 2014). However, even when disruptions take place then peoples' personal preferences still lead to someone deciding to live somewhere else than another person.

3. Methodology

In this chapter the research methodology is described. First the case study area is described in Section 3.1. Secondly the data collection method and dataset are described. Thereafter the research method is described in Section 3.3. The datasets have been processed to meet the research requirements, and various trips and variables have been removed, added and altered as a result (Section 3.4).

3.1 Case study area

Since the turn of the century property values in urban centres have increased. Especially in Amsterdam (figure 3.1) the price of real estate increased faster than the Dutch average (figure 1.1). Concerns over rising property values have been given attention by local media (Khaddari, 2020; Couzy, 2020), national media (VPRO Tegenlicht, 2017; nu.nl, 2017; Van den Eerenbeemt, 2017a; 2017b; Remie, 2016) and academics (Raets, 2005). Property values have risen much faster than the Dutch average (Van den Eerenbeemt, 2017b). Berkers & Dignum (2018) and Savini et al. (2015) found that in Amsterdam the expensive housing segment has grown, thereby reducing the affordable and intermediate housing stock. As a result, low and middle income households report that they are being pushed out of centrally located neighbourhoods in Amsterdam towards the urban fringe and suburban towns (VPRO Tegenlicht, 2017).

RTLZ.nl (2020), involved in business journalism, suggests that people who work in Amsterdam commute longer than people who work in London.People who work in Amsterdam experience longer commuting durations compared to the Dutch average. Local and regional governmental organisations attempt to decrease commuting durations by improving infrastructural links between Amsterdam and surrounding residential locations (Municipality of Amsterdam, 2013; Rijkswaterstaat.nl, n.d.), and the local public transport company (GVB, operating the bus, tram and metro network) focuses on investing in its regional transport facilities (Municipality of Amsterdam, 2013). Examples given are the newly opened north-south line and upgraded bus services between Amsterdam and Almere. as well as by funding initiatives that aim to reduce work-related travelling (Omroepflevoland.nl, 2020).

Figure 3.1
Municipal border of Amsterdam.

According to the Amsterdam Economic Board (2017) the Metropolitan Region of Amsterdam employs one and a half million people, a surplus of 213,000 jobs when compared to the working population of Amsterdam. Little over one million people both resided and worked in the metropolitan region of Amsterdam and another 432,000 people worked in Amsterdam but had their residential location somewhere else (Amsterdam Economic Board, 2017). The outgoing commuting flow is 213,000 people. Where the city used to accommodate relatively more jobs for people holding a lower or middle education degree compared to, recent research (CBS, 2016) shows that the amount of jobs available for high-skilled workers increased in the Amsterdam metropolitan region. Low-skilled jobs are mainly found at the edges of the city, while relatively more high-skilled jobs can be found in centrally located neighbourhoods. Given that property prices at the urban fringe are lower than property prices in centrally located areas and therefore houses relatively more low and middle income households it could be that in Amsterdam low and middle income households experience longer commuting durations and commuting distances when they need to travel to, from or between urban fringes in spite of the investments made to facilitate and optimise traffic flows.

3.2 Data sources

This thesis research employs qualitative research methods to evaluate the extent of how changes in residential and work locations have influenced commuting durations and distances in Amsterdam. It is possible to do so by employing the Dutch national mobility survey (OViN). The respondents participating in the OViN survey have been carefully selected to represent the total population of the Netherlands. As a result the data has been utilised in many researches that monitor mobility behaviour (Municipality of Amsterdam, 2019; CROW, 2016; CROW, n.d.). Respondents tracked their trips for one day, including information about travel distances, travel times and mode of transport. Their trips have been linked to their social and economic information such as household income and age. By applying multiple survey years changes over time can be analysed properly. Being conducted annually by CBS[2] to provide information about travel behaviour of Dutch citizens (CBS, n.d.a), the survey results connect valuable information about commuting behaviour to social and spatial variables. A new sample is taken from the total population annually, making it a repeated cross-section (Van de Coevering, 2012). As a result it is not possible to draw conclusions from changes in residential location, workplace location and commuting behaviour of individual cases, but it is possible to analyse changes of social groups. For this research the OViN datasets of 2010, 2011, 2016 and 2017 are used because of two primary reasons. First, the first OViN survey was conducted in 2010 as an updated version of the mobility survey that ran before 2010. On its turn, from 2018 onwards a new mobility survey replaced OViN. As a result some important social variables (such as income) cannot be compared to data before 2010 and after 2017, making it impossible to execute a proper analysis on changing commuting behaviour. Secondly, after the end of the financial crisis house prices in the Netherlands were at their lowest, followed by rising property values in the years after.

3.2.1 Description of the variables

The OViN dataset consists of many variables that were used in this research, ranging from social-demographic data to information about all trips that the respondent recorded on one day. This

[2] CBS: Centraal bureau voor de Statistieken. English: Statistics Netherlands

paragraph describes the variables that have been extracted from the raw dataset and used for this research. Per variable an overview of the coding of each value is provided in appendix V.

To research changes in peoples' commutes the four OViN datasets have been divided. Here, the 2010 and 2011 datasets will resemble the situation prior to the rise in property values, while the 2016 and 2017 datasets resemble the situation after a period of rising property values.

Commuting time is recorded in minutes, and commuting distance is recorded in kilometres. Both are continuous values.

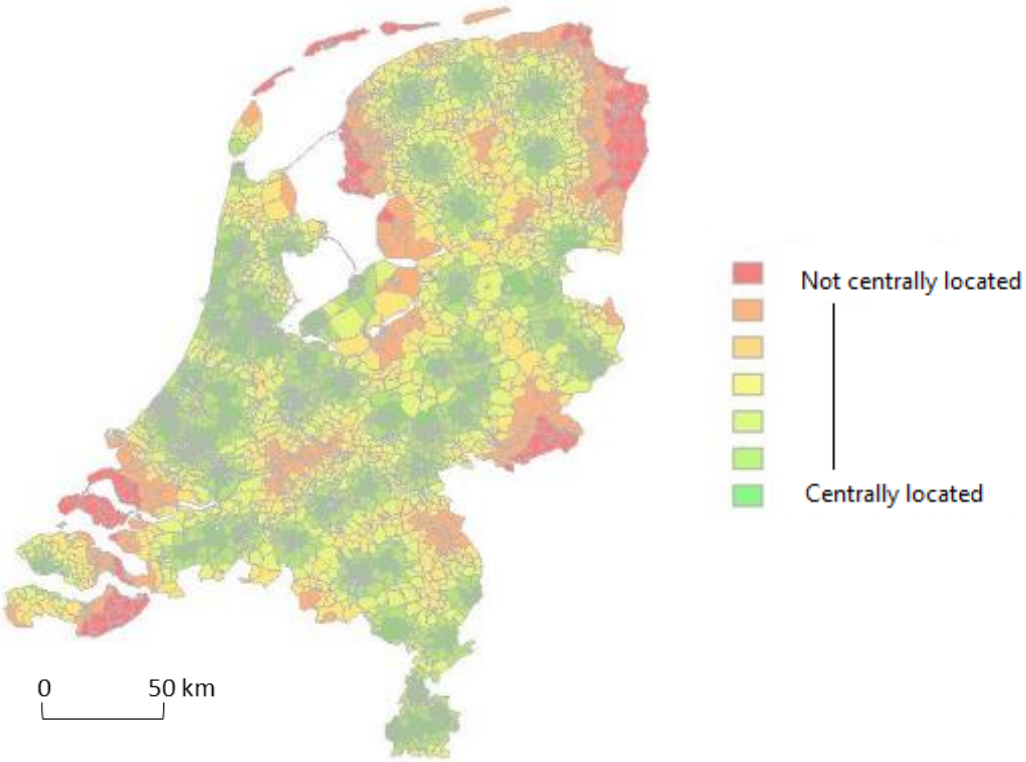
Seven social-demographic variables were used in this research. Gender describes if the respondent is male or female. Age is recorded in years. The highest completed education degree is recorded as lower educated (e.g. primary school (appendix V)), middle educated (e.g. MBO) and higher educated (e.g. university). Household composition was converted into whether or not the household consists of children, and whether the respondent consists of a one-person household or with a partner. Household income was grouped in steps of €10,000 until having an income of €50,000 or more. Income has been standardised by CBS to match that of a one-person household, making it possible to compare between different household compositions (CBS, n.d.c).

The main mode of transport used in the commute have been divided into three categories. Here, "motorised vehicles" consists of car, motorcycle, van, truck, camper, "public transport" consists of train, tram, bus, taxi, touring car, "slow transport" consists of pedestrian, bicycle, scooter and moped (appendix V).

For this research the centrality of the residential and workplace was defined as the euclidean distance (in metres) from peoples' residential and workplace location to the nearest intercity station. The locations of these intercity stations can be found in appendix I. This decision was made because of the central function that transportation hubs have in accessing jobs (Synchroon, 2018), and therefore is a more relevant centrality parameter to research commuting than when using the centre of a town or city. For people that reside in Amsterdam an extra variable was calculated based upon the euclidian distance between peoples' residential location and Amsterdam CS, because this location better represents residing centrally in Amsterdam. ArcGIS was used to calculate the euclidean distances by using the nearest distance tool and data layers containing the latest postal code zones and intercity stations in the Netherlands, both provided by ESRI Netherlands. Figure 3.2 provides an overview of the centrality of each postal code in the Netherlands, green representing the 4-digit postal zones nearer to an intercity station, while red 4-digit postal zones measure a bigger distance to the nearest intercity station.

Interaction variables were calculated to enable researching the connection between income and peoples' residential and workplace location. Without the interaction variables it is only possible to draw conclusions on the effect of income on commuting durations and commuting times. With interaction variables it is possible to research differences in commuting duration and commuting distance between income groups when they live or work less central.

Figure 3.1
Centrality of all 4-digit postal zones in the Netherlands.



Note: Based on all IC stations.

A weight factor variable was used in the analyses in order to cope with the underrepresentation of social groups in the OViN survey. While the participants in the OViN survey were carefully selected some social groups, such as non-western immigrants, fill in surveys because of various reasons such as language barriers. It is important to ensure that the sample groups is a proper representation of the total population. The weight factor is integrated by CBS into the raw datasets. By applying a weight factor the sample groups are a realistic representation of the 1,500,000 people that reside and/or work in Amsterdam (Amsterdam Economic Board, 2017).

3.3 Research method

The main objective of this research is to investigate the extent of which residential and work locations influence commuting durations and distances. Moreover, changes between 2010/2011 and 2016/2017 will be analysed as well to find out if different social groups, particularly when split to income, have changed their commute. The literature review revealed that various spatial and socio-demographic factors are embedded in possible explanations. In order to describe changes in residential location, workplace location and commuting behaviour a spatial analysis was performed. This analysis describes This way it was possible to describe differences between social groups from a spatial point of view. Besides, changes in commuting duration and commuting distance were also described for each social-demographic variable based on the residential and workplace locations.

Ordinary least squares regression models were calculated to estimate the relationship between the dependent variables (*y*) which are commuting duration & commuting distance and the independent variables (*x*). The independent variables (*x*) are residential location centrality, workplace location centrality, income and interaction variables between income and residential & workplace location. Age, gender, household composition, highest completed education & main mode of transport are also included as independent variables. The outcome are four regression models. Two for 2010/2011 and two for 2016/2017. For each 2010/2011 and 2016/2017 there is a seperate regression model for commuting duration and for commuting distance.

The results of the analyses were described. First, the commuting durations and commuting distances were described and compared by making a spatial analysis. Differences in commuting patterns between social groups were described, while separating groups based on their residential and workplace location. This way the increase or decrease of commuting durations and distances were described by using the independent variables. Secondly, the regression models described and explained the effect of the independent variables for people living in Amsterdam. Using the interaction between income and residential & workplace location differences enabled a comparison between income groups.

3.4 Data processing

The raw OViN datasets of 2010, 2011, 2016 and 2017 contain a total of 509,190 cases. The raw dataset was checked and trips were deleted when they did not meet the following criteria:

- "Going to work/coming from work" as trip purpose value.
- Commuting trips start at the residential location and end at the workplace location.
- Either the respondents' residential location or workplace location must be in the municipality of Amsterdam.
- Respondents' residential location and workplace location must be in the Netherlands, because the centrality of people's residential and workplace location is only calculated for Dutch postal zones.

The original OViN datasets contain faulty responses that have to be deleted. For example, one response claimed to have traveled 600 minutes over a distance of 1 kilometre, and another claimed to be below the age of 10 while having a fulltime job. Therefore it is necessary to execute a second data cleaning by deleting untrustworthy responses based on the following variables:

- Respondents have to be between 18 and 67 years old to be included in the dataset to prevent faulty responses. 98.6% of all trips were within this criteria.
- The maximum commuting distance has been set at 120 kilometres one-way. 99% of all trips were within this criteria.
- The maximum commuting time has been set on 120 minutes one-way. 99.1% of all trips were within this criteria.

A total of 2,399 commuting trips remain for the data analysis, of which 1,028 trips are part of the 2010/2011 OViN dataset and 1,310 trips are part of the 2016/2017 OViN dataset. More trips were recorded in 2016 & 2017 because of the efforts of CBS to increase the amount of respondents in the metropolitan area of Amsterdam (Kieft & Grooten, 2015).

Between 2010 and 2017 some minor spatial rezoning has taken place. In the municipality of Amsterdam postal zone 1099 merged to 1114 in 2014. According to Ritsema van Eck & Hilbers (2018) the impact of postal zones being rezoned have insignificant impact on an analysis as performed for this research. In this research very few trips were recorded in postal zone 1099. Trips recorded in postal zone 1099 in 2010 or 2011 have been merged with the trips that were recorded in postal zone 1114.

4. Data analysis

Together with the modelling chapter (chapter 5) the data analysis chapter comprises the results chapter of this report. This chapter focuses on the variables that are utilised in this research. It describes (changes in) peoples' residential location & workplace location and describes and explains differences and changes commuting duration and commuting distance between different social groups.

The data analysis is split into three Sections. First, the data characteristics are presented in Section 4.1. Thereafter, in Section 4.2 the spatial analysis will be presented. In Section 4.3 commuting duration and commuting distance is described for each variable, examining differences between social groups as well as describing changes between 2010/2011 and 2016/2017 for different social groups.

4.1 Data characteristics

Figure 4.1 below visualises the spatial distribution of where respondents reside in the Amsterdam region. A more detailed spatial distribution of where the respondents live can be found in appendix III. The majority of respondents live inside of the A10 motorway, with most 4-digit postal zones consisting of over 12 and 15 respondents in 2010/2011 and 2016/2017 respectively. Some 4-digit postal zones contain fewer respondents, being more apparent for zones outside the A10 motorway. Outside the municipality of Amsterdam respondents are mainly concentrated in agglomerations such as Diemen, Almere, Haarlem and Zaandam. Having fewer respondents in a 4-digit postal zone could result in bigger changes in the mean income, commuting duration and commuting distance. However, as the centrality of the residential and workplace is not bound to a specific 4-digit postal zone this will not influence the data analysis and regression model outcomes.

Figure 4.1
Residential locations of the respondents.

Note: left: 2010/2011, right 2016/2017.

Regarding the workplace location there are three main locations where respondents work. In both 2010/2011 and 2016/2017 people primarily work in the centre of Amsterdam, near Amsterdam Sloterdijk and near Amsterdam Bijlmer (figure 4.1). Additionally, especially in 2016/2017 more people also work near Amsterdam WTC. Outside Amsterdam respondents primarily work in a neighbouring municipality such as Haarlemmermeer (Schiphol, Hoofddorp) or in a city further away (The Hague, Hilversum, Utrecht). A few work somewhere else.

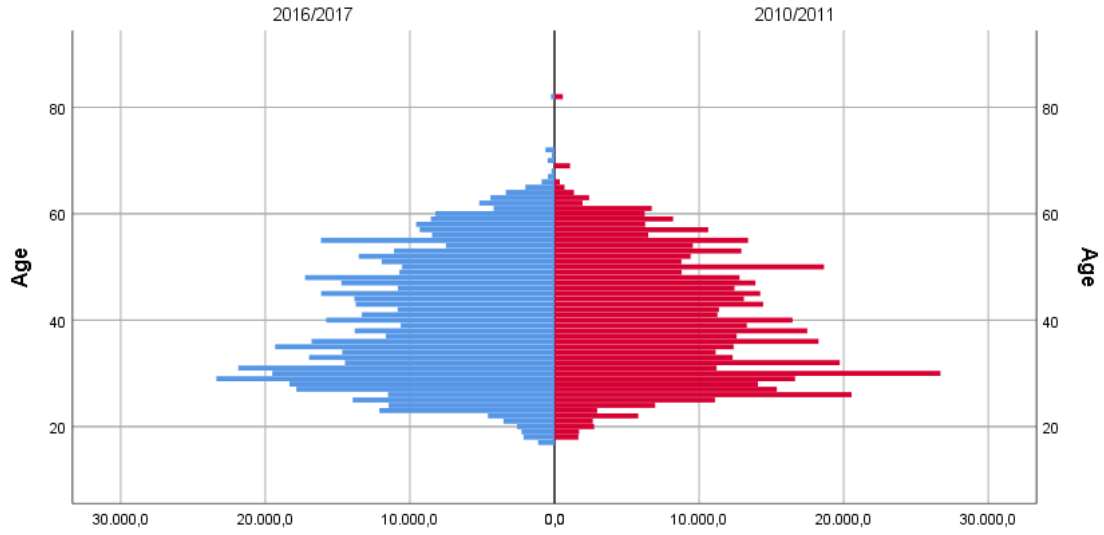
Table 4.1

Respondent count.

		2010/2011		2016/2016	
		Count	Percent	Count	Percent
Gender	Male	299,148	57.5%	334,794	58.5%
	Female	221,365	42.5%	237,322	41.5%
Income	Low income	40,882	7,9%	79,819	14,0%
	Middle income	332,424	63.9%	398,604	69.7%
	High income	147,207	28.3%	93,693	16.4%
Employment	Full time	436,812	83.9%	498,696	87.2%
	Part time	83,701	16.1%	73,420	12.8%
Highest completed education level	Lower vocational education	295,025	56.7%	353,382	61.8%
	Middle vocational education	163,293	31.4%	164,344	28.7%
	Higher professional education	62,195	11.9%	54,390	9.5%
Household lives as couple	Couple	346,003	66.5%	368,359	64.4%
	One-person household	174,511	33.5%	203,757	35.6%
Household includes child(ren)	Household with children	237,322	45.6%	256,768	44.9%
	Household without children	270,572	54.4%	302,341	55.1%
Main mode of transport	Motorised vehicle	226,663	43.5%	226,857	39.7%
	Public transport	130,085	25.0%	171,149	29.9%
	Slow traffic	163,765	31.5%	174,109	30.4%

Note: Weight factor is applied.

Figure 4.2
Age distribution by recording year.



In both datasets the mean age of the respondents is 40 years (figure 4.2), where in 2010/2011 the standard deviation = 11 years, and in 2016/2017 the standard deviation = 12 years. Moreover, in both 2010/2011 and 2016/2017 around 58% of the respondents are male, while 42% of the respondents are female. In 2016/2017 more households have a standardised household income below €20.000, while the share of high income households reduced from 28.3% to 16.4%. The share of middle income households increased slightly from 63.9% to 69.7%. Most of the respondents hold a fulltime job (30 hours/week or more). The share of people that completed a middle vocational education degree or higher professional education degree decreased, while about 3 in 5 people completed a lower vocational education degree. About two out of three people reside as a couple, while one third of the people reside as single. The amount of households that comprise of one or more child(ren) is roughly 52%, while 48% of households reside without children. The share of commuters that travel by motorised vehicle (car, motorcycle) deceased from 43.5% to 39.7%, while the amount of people traveling by foot or bicycle fell from 31.5% to 30.4%. The share of public transport (train, tram, bus) increased by 4.9% to 29.9% in 2016/2017.

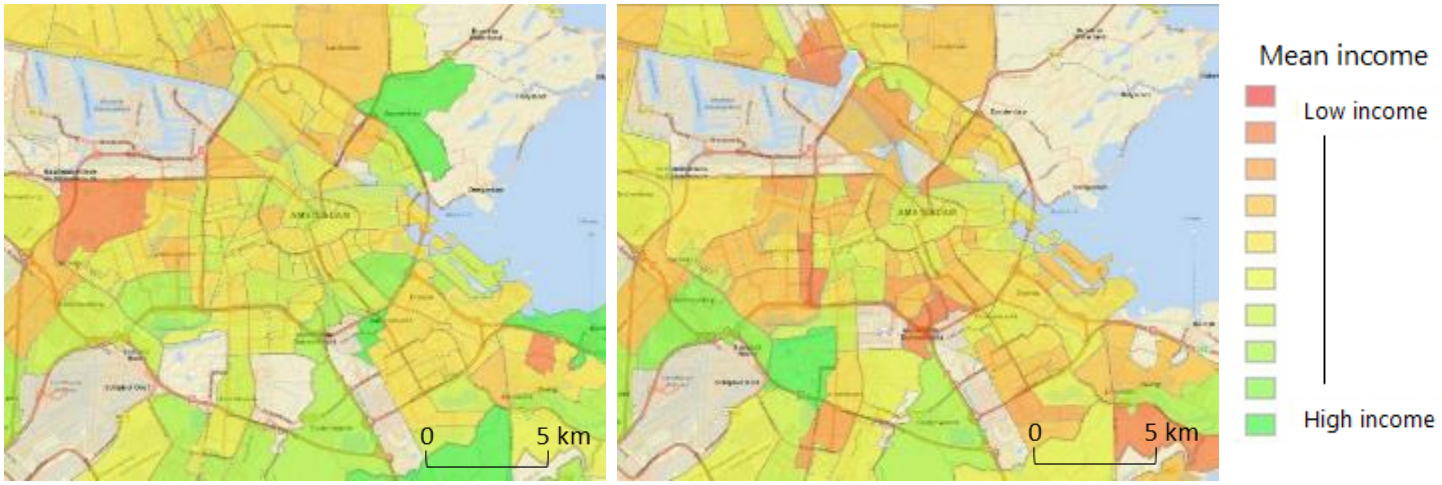
4.2 Spatial analysis

This paragraph describes the spatial analysis, in which for each 4-digit postal zone the average (standardised) household income, commuting duration and commuting distance were calculated for both datasets. Additionally, changes in these variables between have been visualised as well. Not all 4-digit postal zones have the same amount of respondents, and outside the municipality of Amsterdam not all 4-digit postal zones will be represented. This paragraph, however, has the purpose to introduce results of the data analysis and regression models meaning that having empty 4-digit postal zones does not raise an issue for this research. Below the results of the spatial analysis are described, while all the maps that were made can be found in appendix III.

4.2.1 Household income

Figure 4.3

Mean standardised household income per 4-digit postal zone.



Note: left: 2010/2011, right 2016/2017.

Figure 4.3 visualises the average income of each 4-digit postal zone in 2010/2011 and 2016/2017. When a 4-digit postal zone is green it means that the average household income is high, while when a postal zone is red the average household income is low. By looking at the maps it becomes apparent that in 2010/2011 the average household income is higher when people live 5-15 kilometres outside the municipal boundary of Amsterdam compared to those residing in Amsterdam or residing more than 15 kilometres from Amsterdam. In Amsterdam people residing near Amsterdam CS and Amsterdam WTC have a higher household income than those residing somewhere else in Amsterdam.

In 2016/2017 the average household income increased both in Amsterdam and outside Amsterdam. The average household income rose especially for people residing inside the Ring A10 but outside the city centre. Differences in average household income between 4-digit postal zones grew smaller.

4.2.2 Commuting distance

It makes sense that people who reside further away from Amsterdam commute further when they work in Amsterdam compared to people residing in Amsterdam, because most of the people residing in Amsterdam work in Amsterdam as well while only a small share works outside Amsterdam. Some 4-digit postal zones in Amsterdam record a higher average commuting distance than neighbouring postal zones. In these cases a higher share of people work outside Amsterdam.

Figure 4.4

Mean commuting distance per 4-digit postal zone.

Note: left: 2010/2011, right 2016/2017.

In most neighbourhoods the average commuting distance increased, however, some exceptions exist. The 4-digit postal zones that do report a lower commuting distance in 2016/2017 recorded a higher than average commuting distance in 2010/2011. In 2016/2017 especially postal zones situated east of Amsterdam CS or situated north of Amsterdam WTC report a lower average commuting distance than neighbouring postal zones. Additionally, some postal zones west of the Ring A10 report a reduction in the average commuting distance (figure 4.4).

4.2.3 Commuting duration

People that reside in a municipality adjoining the municipality of Amsterdam have a comparable average commuting duration as people that reside in Amsterdam, with most neighbourhoods having an average commuting duration between 15-30 minutes or 30-45 minutes. This is caused because 1) people that reside in Amsterdam more often make use of slow mode of transport (bicycle or by foot) or by public transport whereas people that reside outside Amsterdam more often make use of motorised transport such as the automobile. Secondly, the average commuting duration of people that live in Amsterdam increases due to people that reside in Amsterdam but work outside Amsterdam or somewhere on the other side of the city. This is also way some 4-digit postal zones in Amsterdam have a higher than average commuting duration, as in these neighbourhoods a higher share of commuters work outside Amsterdam. The average commuting duration increases when people reside further away from Amsterdam, because they have to travel further in order to get to Amsterdam.

Figure 4.5

Mean commuting duration per 4-digit postal zone.

Note: left: 2010/2011, right 2016/2017.

The mean commuting duration decreased especially for those residing near Amsterdam CS, Amsterdam WTC and Amsterdam Slotervaart. On the contrary, the average commuting duration increased especially for those residing near the Canal District, Amsterdam Zuidoost and in Amsterdam West. As a result the difference in average commuting durations between 4-digit postal zones became smaller (figure 4.5). Outside Amsterdam there are both neighbourhoods where the commuting duration increased as well as where the commuting duration decreased, primarily caused because the data set only consists of a few respondents per 4-digit postal zone in these areas, resulting in bigger changes because there are substantial differences in commuting patterns between these respondents.

4.3 Analysis based on factors that influence commuting

4.3.1 Tables based on variables

The mean commuting duration increased from 37.8 minutes (*st. Dev.* = 23.1 minutes) in 2010/2011 to 39.9 minutes (*st. Dev.* = 22.9 minutes) in 2016/2017. Moreover, the mean commuting distance has also increased from 21.7 kilometres (*st. Dev.* = 20.8 kilometres) in 2010/2011 to 24.6 kilometres (*st. Dev.* = 22.7 kilometres) in 2016/2017. Whether or not someone resides in Amsterdam or somewhere else affects their commuting duration and commuting distance. In 2010/2011 people that reside outside Amsterdam commute 17.6 minutes longer and 18.2 kilometres farther than people who reside in Amsterdam. in 2016/2017 people who reside outside Amsterdam commute 20 minutes longer and 22.1 kilometres farther than people who reside in Amsterdam. People who reside outside Amsterdam have to work in Amsterdam in order to be part of the sample group. The respondents that live in Amsterdam either work in Amsterdam or work somewhere else, which means that these respondents on average have to commute shorter than those residing outside Amsterdam.

Section 4.3.1 describes differences between social groups based on the variables that are included in the analysis. Section 4.3.2 describes differences in commuting duration, commuting distance and household income based on the residential and workplace location.

For each nominal and ordinal socio-demographic variable the mean and standard deviation commuting duration and commuting distance are shown in table 4.2 and table 4.3. It shows that males travel farther and longer than females, although females did travel slower in 2016/2017 than in 2010/2011 as their commuting duration increased stronger than their commuting distance. Hence, the difference in commuting duration did get smaller.

The commuting duration and commuting distance of high income households worsened, while the commuting duration and commuting distance of low and middle income households remained more or less the same. This is the case for both people residing in Amsterdam as well as for people residing elsewhere. As a result low income households now commute the shortest followed by middle income households, while in 2010/2011 high income households commuted the shortest followed by low income households.

Part time employees commute shorter than full time employees, although part time workers do commute slower than full time workers.

People that hold a lower vocational education degree commute shorter than those holding a middle vocational education degree, while people holding a higher professional education degree commute the longest and farthest.

People that live together with a spouse commute longer and farther than singles. Moreover, households without children commute longer and farther than households with children. In 2016/2017 households with children and households without children recorded a comparable commuting distance.

People that commute by motorised vehicle travel the fastest, but also commute longer and farther than those commuting by bicycle or foot because people that commute by a slow mode of transport reside nearer to their workplace location. People that commute by public transport commute the longest and farthest in 2010/2011, whereas they commute a shorter distance in 2016/2017 (here their commuting duration is longer than those commuting by motorised vehicle). People that commute by public transport thus travel slower than those traveling by motorised transport, but they travel faster than those commuting by bicycle or on foot.

Age is not displayed in the tables because it is a continuous variable. A negligible difference in commuting duration and commuting distance exists between younger and older workers, as older workers commute a little bit shorter than younger workers. Per year of age peoples commuting duration and commuting distance reduces by a few seconds or metres.

Table 4.2

Mean commuting duration.

		2010/2011						2016/2017					
		Amsterdam		Other		Total		Amsterdam		Other		Total	
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Total		30.5	20.3	48.1	22.8	37.8	23.1	31.0	19.8	51.0	21.7	39.9	22.9
Gender	Male	31.0	20.4	48.9	22.5	39.2	23.2	31.1	20.3	51.0	21.7	40.5	23.2
	Female	30.0	20.1	46.6	23.3	35.9	22.8	30.9	19.1	51.1	21.7	39.0	22.5
Income	Low income	29.4	21.3	48.8	25.5	35.2	24.3	29.0	20.4	50.3	21.5	35.1	22.9
	Middle income	31.2	20.0	48.6	22.4	39.3	22.8	31.6	19.4	50.9	21.9	40.7	22.8
	High income	29.3	17.3	42.8	18.8	35.6	19.3	31.4	20.3	52.3	20.7	41.4	23.0
Employment	Full time	31.5	20.5	48.2	22.7	38.8	23.0	31.5	18.9	51.3	21.7	40.5	22.5
	Part time	26.1	18.7	47.5	23.2	32.7	22.5	28.1	24.2	48.8	21.6	35.9	25.3
Highest completed education level	Lower education degree	26.8	18.5	47.5	23.3	35.2	22.9	30.9	23.9	42.9	19.0	36.2	22.7
	Middle education degree	29.1	18.2	47.5	22.0	38.1	22.2	30.0	17.3	49.2	22.0	39.8	22.0
	Higher education degree	31.9	21.4	48.6	23.2	38.2	23.5	31.4	20.0	53.4	21.5	40.5	23.3
Household lives as couple	Couple	31.6	20.6	48.9	22.5	40.0	23.2	31.2	19.4	50.8	21.4	41.1	22.7
	One-person household	28.8	19.6	45.1	23.7	33.4	22.1	29.6	18.6	51.5	22.5	36.8	22.5
Household includes children	Household with children	28.2	17.6	46.5	22.5	37.6	22.2	29.8	17.2	49.9	21.2	40.8	21.9
	Household without children	32.0	21.7	50.2	23.1	38.2	23.8	30.9	20.1	52.3	22.3	38.8	23.3
Main mode of transport	Motorised vehicle	31.4	19.0	42.4	19.3	37.6	19.9	32.0	20.1	43.1	18.2	38.5	19.8
	Public transport	51.1	21.3	64.9	19.6	58.4	21.6	47.0	21.2	64.7	19.6	57.1	22.1
	Slow traffic	20.9	12.4	27.3	17.4	21.7	13.3	22.5	12.5	37.6	17.1	24.4	14.1

Table 4.3

Mean commuting distance.

		2010/2011						2016/2017					
		Amsterdam		Other		Total		Amsterdam		Other		Total	
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Total		14.1	16.9	32.2	21.2	21.7	20.8	14.8	18.3	36.9	21.7	24.6	22.7
Gender	Male	14.4	17.3	34.8	21.4	23.7	21.8	16.6	20.9	39.5	22.5	27.4	24.5
	Female	13.8	16.5	27.9	20.0	18.9	19.1	12.6	14.2	32.8	19.6	20.7	19.3
Income	Low income	12.4	16.2	31.9	20.7	18.1	19.8	11.3	13.4	32.2	16.9	17.3	17.3
	Middle income	15.2	17.4	32.6	22.0	23.3	21.5	15.0	17.6	36.9	22.0	25.4	22.6
	High income	13.7	15.5	29.8	14.9	21.2	17.2	19.2	25.5	40.0	22.5	29.1	26.3
Employment	Full time	15.0	17.5	32.9	21.5	22.8	21.3	15.7	18.8	38.1	21.9	25.9	23.1
	Part time	10.3	13.5	27.6	18.3	15.6	17.1	9.3	13.8	27.3	17.2	16.1	17.5
Highest completed education level	Lower education degree	10.2	9.1	32.7	21.3	19.3	18.9	11.8	13.3	38.6	26.8	23.6	24.4
	Middle education degree	12.6	13.5	31.1	19.8	21.6	19.2	13.6	14.4	34.9	21.4	24.4	21.2
	Higher education degree	15.6	19.2	33.0	22.1	22.2	22.0	15.7	20.1	37.9	20.8	24.8	23.1
Household lives as couple	Couple	15.7	18.0	33.8	21.6	24.4	21.8	15.6	19.4	36.7	21.5	26.3	23.0
	One-person household	11.8	14.8	26.6	18.7	16.0	17.3	12.9	15.8	37.6	22.4	21.1	21.6
Household includes children	Household with children	12.4	13.3	30.8	20.2	21.9	19.5	14.6	16.9	35.7	21.6	26.2	22.2
	Household without children	15.3	18.8	34.1	22.3	21.6	21.9	14.5	18.8	38.3	21.8	23.3	23.0
Main mode of transport	Motorised vehicle	21.2	18.5	33.3	20.0	28.0	20.3	25.6	23.3	38.8	21.7	33.3	23.3
	Public transport	24.3	20.9	37.3	21.6	31.1	22.2	20.7	18.3	39.9	20.2	31.7	21.6
	Slow traffic	4.7	3.6	9.2	7.6	5.3	4.6	5.0	3.4	11.9	6.6	5.9	4.5

4.3.2 Tables based on residential and workplace location

Table 4.4

Respondent count (weight factor applied) in 2010/2011.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Total*
Workplace location	Central Amsterdam CS	1,376	0	1,458	10,737	753	11,037	25,361
	Central Amsterdam WTC	0	1,557	533	8,632	162	12,693	23,577
	Central elsewhere in Amsterdam	403	1,903	21,930	103,525	17,046	88,241	233,048
	Not central in Amsterdam	1,722	589	16,643	55,093	11,933	75,130	161,109
	Central elsewhere outside Amsterdam	1,740	535	17,82	25,085			29,141
	Not central outside Amsterdam	438	,1077	14,909	44,906			61,330
	Total	5,679	5,661	57,255	247,977	29,894	187,100	533,566

Table 4.5

Respondent count (weight factor applied) in 2016/2017.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Total*
Workplace location	Central Amsterdam CS		698	1,435	10,812	1,629	12,091	26,666
	Central Amsterdam WTC		720	807	6,487	2,488	18,964	29,465
	Central elsewhere in Amsterdam	4,211	3,619	26,934	107,566	17,107	113,194	272,632
	Not central in Amsterdam		255	17,952	52,629	14,965	70,223	156,024
		98	1,127	6,173	20,471			27,869

	Central elsewhere outside Amsterdam							
	Not central outside Amsterdam	1,833	1,162	14,561	49,767			67,324
	Total	6,142	7,580	67,862	247,732	36,190	214,472	579,979

Table 4.4 and table 4.5 show where respondents in the sample reside and work (including the weight factor). All tables, including the amount of respondents without weight factor, can be found in appendix IV. These locations are divided into 1) Amsterdam CS, 2) Amsterdam WTC, 3) central elsewhere in Amsterdam, 4) not central in Amsterdam, 5) central elsewhere outside Amsterdam, and 6) not central outside Amsterdam. Apart from Amsterdam CS and Amsterdam Zuid/WTC, the neighbourhoods situated within 2.4 kilometres -or the average distance someone is able to cycle in 10 minutes- of the railways stations Amsterdam Bijlmer, Amsterdam Amstel or Amsterdam Sloterdijk. A limited amount of respondents reside and/or work central near Amsterdam CS or Amsterdam WTC. The average income, commuting duration and commuting distance will be affected by individuals as a result. Because these tables are meant to contribute to the other analyses this is not an issue for the further analyses.

Household income

Table 4.6

Mean household income in 2010/2011.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS	2.00	-	2.50	1.88	1.00	2.29	2.07
	Central Amsterdam WTC	-	1.47	2.00	2.80	2.00	2.79	2.69
	Central elsewhere in Amsterdam	4.00	1.46	2.30	2.02	2.35	2.40	2.21
	Not central in Amsterdam	3.63	4.00	1.66	2.16	2.72	2.66	2.40
	Central elsewhere outside Amsterdam	3.10	5.00	3.21	2.32	-	-	2.47
	Not central outside Amsterdam	3.00	3.00	2.02	2.09	-	-	2.10
	Average	3.05	2.36	2.07	2.11	2.46	2.52	2.29

Table 4.7

Mean household income in 2016/2017.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS	-	2.00	1.35	2.24	1.36	2.65	2.32
	Central Amsterdam WTC	-	1.91	4.00	2.33	4.15	2.98	2.94
	Central elsewhere in Amsterdam	3.21	2.70	2.47	2.56	2.68	2.95	2.73
	Not central in Amsterdam	-	5.00	2.60	2.72	2.67	3.13	2.89
	Central elsewhere outside Amsterdam	4.00	3.03	2.56	3.01	-	-	2.91
	Not central outside Amsterdam	2.98	3.07	2.85	2.72	-	-	2.76
	Average	3.16	2.75	2.59	2.64	2.71	3.00	2.78

Table 4.6 shows the mean household income In 2010/2011, while table 4.7 shows the mean household income in 2016/2017 and the change between these data sets. Here, a figure of 1 would indicate that all people have an income of below €10,000, while a figure of 5 would indicate that all people have an income above €50,000. People who reside near Amsterdam CS have the highest income, followed by those residing not central outside Amsterdam. People who reside centrally elsewhere in Amsterdam have the lowest income, followed by those residing not central in Amsterdam. Regarding the workplace location it becomes clear that people who work central near Amsterdam WTC have the highest income, followed by those who work centrally outside Amsterdam. People who work near Amsterdam CS have the lowest income, followed by those working not central outside Amsterdam. The mean income increased. Here, peoples' income grew the most for people who reside in Amsterdam, but not near Amsterdam CS or Amsterdam WTC. Additionally, people who work not central in Amsterdam also saw their income increase more than average. On the whole the difference in income levels became smaller between 2010/2011 and 2016/2017. However, for 2016/2017 people still earn the most when they reside or work at the same locations as originally.

Table 4.8

Mean commuting duration in 2010/2011.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS	24.3	-	17.5	19.3	32.0	45.4	31.2
	Central Amsterdam WTC	-	15.0	15.0	29.7	64.0	44.7	39.9
	Central elsewhere in Amsterdam	52.0	26.6	22.4	23.2	58.3	46.3	34.5
	Not central in Amsterdam	24.4	45.0	19.5	34.9	54.6	48.5	41.0
	Central elsewhere outside Amsterdam	91.5	30.0	34.2	50.9	-	-	51.9
	Not central outside Amsterdam	50.0	36.6	42.2	47.4	-	-	46.0
	Average	48.9	40.9	26.9	33.0	56.2	47.0	37.8

Table 4.9

Mean commuting duration in 2016/2017.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS	-	30.0	15.2	25.5	61.1	49.8	38.3
	Central Amsterdam WTC	-	15.6	22.0	25.1	60.1	43.2	39.4
	Central elsewhere in Amsterdam	29.2	19.7	22.6	25.1	59.0	49.8	37.2
	Not central in Amsterdam	-	20.0	24.3	26.7	54.2	52.5	40.6
	Central elsewhere outside Amsterdam	75.0	48.1	54.0	54.6	-	-	54.3

	Not central outside Amsterdam	52.6	45.8	42.9	45.2	-	-	44.9
	Average	36.9	28.5	30.1	31.9	57.2	50.1	39.9

People that reside centrally elsewhere in Amsterdam have a shorter commuting duration than those that do not reside centrally or that reside outside Amsterdam. The majority of people that reside and work in Amsterdam commute less than 25 minutes. People that reside in Amsterdam but work outside Amsterdam travel 47 minutes, although this is on average 5 minutes shorter than those residing outside Amsterdam and working in Amsterdam. The mean travel time of the whole sample increased. However, people that reside in Amsterdam have a shorter commuting duration in 2016/2017, except for people that reside central elsewhere in Amsterdam (table 4.8 & 4.9). The commuting duration of people that reside outside Amsterdam increased. People that reside or work not central outside Amsterdam commute shorter than those residing or working central outside Amsterdam.

Commuting distance

Table 4.10

Mean commuting distance in 2010/2011.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS	-	5.3	8.3	6.8	40.3	28.5	18.8
	Central Amsterdam WTC	-	1.6	4.0	5.2	48.6	28.6	23.8
	Central elsewhere in Amsterdam	6.5	6.2	6.0	7.1	38.7	37.5	21.5
	Not central in Amsterdam	-	10.0	7.2	7.5	43.1	37.2	24.3
	Central elsewhere outside Amsterdam	53.0	26.5	31.1	39.3	-	-	37.0
	Not central outside Amsterdam	40.2	31.1	28.0	36.8	-	-	34.9
	Average	17.3	12.6	13.4	15.7	41.2	36.1	24.6

Table 4.11

Mean commuting distance in 2016/2017.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS	3.0	-	5.5	6.1	23.7	30.9	17.2
	Central Amsterdam WTC	-	2.0	5.0	7.1	53.5	25.3	20.3
	Central elsewhere in Amsterdam	19.4	7.6	5.1	7.3	37.0	31.1	18.3
	Not central in Amsterdam	4.9	9.0	4.8	7.4	38.7	33.2	21.4
	Central elsewhere outside Amsterdam	73.8	55.0	22.9	42.3	-	-	43.2
	Not central outside Amsterdam	36.6	33.9	26.6	31.8	-	-	30.6
	Average	29.0	30.0	11.2	15.2	37.4	31.5	21.7

Originally the commuting distance of people residing centrally in Amsterdam was further than the commuting distance of people residing centrally elsewhere in Amsterdam or not central in Amsterdam (table 4.10). In 2016/2017 the difference in commuting distance was much smaller (table 4.11). Here, peoples' commuting distance decreases when they work more centrally in Amsterdam. Just as for the commuting duration, the mean commuting distance increased. People that reside in Amsterdam saw their commuting distance increase much less, or even saw their commuting distance decrease. People that reside outside Amsterdam, however, saw their commuting distance increase more than average. Especially people residing in Amsterdam but working centrally outside Amsterdam have a shorter commuting distance in 2010/2011 than in 2016/2017. However, these people still have the farthest commutes.

4.3.3 Change in residential location split by household income

The share of low income respondents has decreased from 28% to 16%, while the share of middle and high income households had increased from 64% to 69% and from 8% to 14% respectively. The mean distance between peoples' residential location and Amsterdam CS decreased for low income households, while the mean distance increased for middle income households (table 4.12).

Table 4.12

Mean distance between residential location and Amsterdam CS/nearest IC station.

		Residential Location			
		Outside Amsterdam		Inside Amsterdam	
		2010/2011	2016/2017	2010/2011	2016/2017
Centrality of residential location	low income	9.83	6.68	7.33	6.78
	Middle income	9.64	8.30	6.80	7.20
	High income	9.03	8.58	6.13	6.44

Note: Outside Amsterdam: nearest IC station, inside Amsterdam: Amsterdam CS.

Low income households reside significantly more often in Amsterdam, and less often reside outside Amsterdam whilst working in Amsterdam (table 4.13). Middle and high income households more often reside outside Amsterdam whilst working in Amsterdam. In Amsterdam high income households now more often reside near Amsterdam CS, while low income households more often reside near another intercity station in Amsterdam that is not Amsterdam CS. The residential locations of middle income households did not change as much as for low and high income households, with a small reduction in households residing not central in Amsterdam.

In 2016/2017 low income households reside More central than in 2010/2011. The same is true for high income households. Middle income households on average reside less central in 2016/2017 than in 2010/2011.

Table 4.13

Residential locations split by standardised household income.

		Low income	**Middle income**	**High income**
2010/2011	Central near Amsterdam CS	2.7%	1.9%	2.6%
	Central elsewhere in Amsterdam	14.4%	9.5%	11.8%
	Not central in Amsterdam	53.5%	42.3%	38.9%
	Central outside Amsterdam	3.5%	6.4%	4.5%
	Not central outside Amsterdam	26.0%	39.9%	42.3%
2016/2017	Central near Amsterdam CS	1.9%	2.0%	4.3%
	Central elsewhere in Amsterdam	19.5%	10.4%	8.9%
	Not central in Amsterdam	50.1%	40.4%	39.2%
	Central outside Amsterdam	5.6%	6.7%	5.4%
	Not central outside Amsterdam	22.9%	40.4%	42.2%

5. Modelling commuting duration and commuting distance

Four regression models have been created in order to, together with the data analysis in the previous chapter, research the extent that peoples' residential location and workplace location influences their commuting duration and commuting distance. The literature revies revealed that peoples' commuting behaviour is affected by many social and spatial factors. A total of 8 independent variables (appendix V) are employed to predict commuting duration and commuting distance. Multiple linear regression was used because not one socio-demographic or spatial variable determines someone's commuting duration or commuting distance independently. In addition to the eight independent variables two interaction variables are calculation in which the interaction effect between 1) the residential location centrality and household income and 2) the workplace location centrality and household income are displayed.

5.2 Multicollinearity

An important step in multiple linear regression is to ensure that no multicollinearity, a statistical phenomenon in which independent variables are highly correlated (Plotts, 2011), exists between the independent variables. To test the 9 independent variables for multicollinearity Pearson Correlations were calculated. The results for the datasets can be found in appendix VI. No two variables are closely related, as none reached the 0.80 correlation threshold.

5.1 Commuting duration

Two regression models are calculated to predict the dependent variable commuting duration based on the independent variables. The first model (table 5.1) uses the commuting trips of 2010/2011, while the second model (table 5.2) uses the commuting trips of 2016/2017.

Table 5.1

Regression output commuting duration 2010/2011 (in minutes).

	B	Std. Error	ß	p
(constant)	26.908	.170		.000
Residential location distance (per km from Amsterdam CS)	-.134	.012	-.023	.000
Workplace location distance (per km from nearest IC station)	1.402	.024	.234	.000
Low income	.865	.131	.025	.000
Middle income	4.734	.123	.147	.000
Interaction low income*residential location distance	.186	.014	.043	.000
Interaction middle income*residential location distance	-.396	.014	-.098	.000
Interaction low income*workplace location distance	-.608	.025	-.093	.000
Interaction middle income*workplace location distance	-.682	.025	-.111	.000
Age	.026	.003	.014	.000
Female	.030	.032	.001	.337
Lower educated	-2.070	0.64	-.072	.000
Middle educated	-.829	.049	-.036	.000
Employed part time	.808	.041	.031	.000
Household includes child(ren)	-2.165	.035	-.104	.000
Household consists of couple	2.404	.035	.116	.000
Public transportation	17.289	.050	.614	.000
Slow traffic	-13.459	.042	-586	.000
N = 489				
R^2= .371				

The regression model for commuting duration in 2010/2011 shows that except gender all independent variables were significant at the 0.05 level. For gender p = .337. R^2 = .371, meaning that the independent variables predict 37.1% of the dependent variable commuting duration. Peoples' commuting duration decreases by .134 minute for each kilometre that someone resides further away from Amsterdam CS. Peoples' commuting duration increases by 1.402 minutes with each kilometre that someone works further away from the nearest intercity station. Here, the commute of low and middle income households increases respectively .608 and .682 minutes less per kilometre than for high income households. People with a low income travel .865 minute longer than those with a high income, while people with a middle income travel 4.734 minutes longer than high income commuters. The commuting duration of low income commuters increases more than for high income commuters when they reside further away from Amsterdam CS. The model shows that for each kilometre of residing farther away from Amsterdam CS the commuting duration of low income commuters increases .186 minute more than the commuting duration increases for high income commuters. The commuting duration of middle income commuters increases by .396 minute less for each kilometre they reside further away from Amsterdam CS than it does for high income commuters.

When examining the effect of residing farther away from Amsterdam CS by splitting to income it becomes apparent that the commute of low income households lengthens by .186 minute per

kilometre in comparison to high income households. The commute of middle income households, however, improves by .396 minute for each kilometre they reside farther away from Amsterdam CS in comparison to high income households. As a result low income households are commuting longer when they reside less central, whereas high and middle income households commute shorter when they reside less central.

Older people commute slightly longer than younger people (.026 minute increase per year of age). Regarding peoples' gender, being an insignificant predictor, only a small difference exists between males and females, where females travel .030 minute longer than males. People that are lower educated travel 2.070 minutes shorter than those being higher educated (HBO, university level), and people that are middle educated travel .808 minute less than higher educated people. People that are employed part time commute .808 minute shorter than full time employees. Households consisting of children commute 2.165 minutes less than households without children, and couples commute 2.404 minutes longer than singles. People that commute by public transport travel 17.289 minutes longer than those travelling by motorised vehicle, while bicyclists and pedestrians commute 13.459 minutes shorter than people travelling by motorised vehicle.

Table 5.2
Regression output commuting duration 2016/2017 (in minutes).

	B	Std. Error	ß	p
(constant)	25.156	.148		.000
Residential location distance (per km from Amsterdam CS)	.077	.011	.015	.000
Workplace location distance (per km from nearest IC station)	1.223	.009	.240	.000
Low income	-4.481	.130	-.136	.000
Middle income	1.399	.100	.053	.000
Interaction low income*residential location distance	.262	.015	.060	.000
Interaction middle income*residential location distance	.101	.012	.032	.000
Interaction low income*workplace location distance	.457	.013	.079	.000
Interaction middle income*workplace location distance	-.433	.011	-.097	.000
Age	.022	.003	.014	.000
Female	-.602	.031	-.031	.000
Lower educated	-1.998	.071	-.069	.000
Middle educated	.776	.053	.035	.000
Employed part time	1.226	.045	.045	.000
Household includes child(ren)	-.230	.034	-.012	.000
Household consists of couple	-.570	.033	-.029	.000
Public transportation	13.861	.049	.526	.000
Slow traffic	-9.801	.042	-.444	.000
N = 717 *R^2= .291*				

The regression model for 2016/2017 shows that all independent variables are significant predicters at the 0.05 level. R^2 = .291, meaning that the independent variables predict 29.1% of the dependent variable commuting duration. Peoples' commuting duration increases by .077 minutes for each kilometre that someone resides further away from Amsterdam CS. Moreover, for each kilometre that someone works further away from the nearest intercity station their commuting duration increases by 1.223 minutes. People with a low income travel less than those with a high income, while people with a middle income travel the longest. When looking at the interaction between peoples' residential location and their income it becomes clear that residing further away from Amsterdam CS leads to the biggest increase in commuting duration for people with a low income. The commuting duration of people with a low income increases .262 minute more when they reside one kilometre further away from Amsterdam CS than when someone with a high income would reside one kilometre further away from Amsterdam CS. The same is true when comparing middle incomes and high incomes, as their commuting duration increases .101 minute more than for high income commuters. The interaction effect between the workplace location and someone's income shows that the commuting duration of people with a low income increases stronger than for people with a high income when they work further away from the nearest intercity station. In fact, for each kilometre that someone with a low income works further away from the nearest intercity station their commuting duration increases .457 minute more than for people with a high income. On the contrary, the commuting duration of people with a middle income increases .433 minute less than for high income households when they work one kilometre further away from the nearest intercity station.

Young people commute slightly shorter than older people. Women travel .602 minutes shorter than men. People that a employed part time commute 1.998 minutes less than those being employed full time. Households that include children commute longer (.230 minute) than households without children. Couples commute longer than single people (.570 minute). People with a low education degree commute shorter than people with a high education degree (1.998 minutes), while people with a middle vocational education degree travel the longest: .776 minute longer than people with a high education degree. Commuters that travel by public transport commute 13.861 minutes longer than people that commute with a motorised vehicle, while people that commute by bicycle or by foot commute 9.801 minutes less than those commuting with a motorised vehicle.

5.2 Commuting distance

Just as for commuting duration two regression models have been calculated to predict the dependent variable commuting distance based on the independent variables. Again, the first model (table 5.3) uses the commuting trips of 2010/2011, while the second model (table 5.4) uses the commuting trips of 2016/2017.

Table 5.3

Regression output commuting distance 2010/2011 (in kilometres).

	B	Std. Error	ß	p
(constant)	19.436	.140		.000
Residential location distance (per km from Amsterdam CS)	-.342	.010	-.072	.000
Workplace location distance (per km from nearest IC station)	.785	.020	.157	.000
Low income	-3.811	.108	-.131	.000
Middle income	4.857	.102	.181	.000
Interaction low income*residential location distance	.270	.012	.076	.000
Interaction middle income*residential location distance	-.514	.011	-.152	.000
Interaction low income*workplace location distance	.426	.021	.078	.000
Interaction middle income*workplace location distance	-.090	.020	-.018	.000
Age	-.137	.002	-.090	.000
Female	.306	.026	.018	.000
Lower educated	-1.373	.053	-.057	.000
Middle educated	-.885	.041	-.046	.000
Employed part time	-.087	.034	-.004	.010
Household includes child(ren)	-2.047	.029	-.118	.000
Household consists of couple	2.045	.029	.118	.000
Public transportation	8.233	.041	.350	.000
Slow traffic	-12.142	.035	-.632	.000
N = 489				
R^2= .369				

The regression model for 2010/2011 shows that except for the variable employment all independent variables were significant predictors at the 0.05 level. Employment is a significant predictor of commuting distance at the .010 threshold. R^2 = .369, meaning that the independent variables predict 36.9% of the dependent variable commuting distance. Peoples' commuting distance decreases by .342 kilometre for each kilometre that someone resides further away from Amsterdam CS. Peoples' commuting distance increases by .785 kilometre for each kilometre they work farther away from the nearest intercity station. People with a low income commute 3.811 kilometres less than those with a high income, whereas people with a middle income travel 4.857 minutes more than high income commuters. Therefore there is a big difference between low income commuters and middle income commuters, as middle income commuters travel significantly farther than low income commuters.

When looking at the interaction variables it becomes clear that the commuting distance of low income commuters increases more than for high income commuters when they reside further away from Amsterdam CS or work further away from the nearest intercity station. The commuting distance of low income households increases .270 kilometre more for each kilometre they reside further away from Amsterdam CS and .426 kilometre more for each kilometre they work further away from the nearest intercity station. For middle income commuters the opposite is true. Here, the increase in commuting distance when middle income commuters reside farther away from Amsterdam CS increases to a lesser extent than for commuters with a high income.

Compared to high income workers the commuting distance of middle income households increases .514 kilometre less for each kilometre they reside further away from Amsterdam CS and .090 kilometre less for each kilometre they work further away from the nearest intercity station.

With each additional year of age people commute .137 kilometre shorter. Females commute .306 kilometre more than males. Low educated people commute 1.373 kilometres less than high educated people, while middle educated people commute .885 kilometre less than high educated people. People that are employed part time travel slightly less (.087 kilometre; p = .010) than full time employees. When a household consists of children then their commuting distance is 2.047 kilometres shorter than households without children. Couples commute 2.045 kilometres further than singles. People that commute by public transportation travel 8.233 kilometres more than those travelling by motorised vehicle, while people that travel by bicycle or by foot travel 12.142 kilometres less than those travelling with a motorised vehicle.

Table 5.4

Regression output commuting distance 2016/2017 (in kilometres).

	B	Std. Error	ß	p
(constant)	11.897	.132		.000
Residential location distance (per km from Amsterdam CS)	-.187	.010	-.039	.000
Workplace location distance (per km from nearest IC station)	1.614	.008	.334	.000
Low income	-2.744	.116	-.088	.000
Middle income	.894	.089	.036	.000
Interaction low income*residential location distance	-.045	.014	-.011	.001
Interaction middle income*residential location distance	.280	.011	.094	.000
Interaction low income*workplace location distance	-.001	.012	.000	.919
Interaction middle income*workplace location distance	-.712	.010	-.169	.000
Age	-.042	.002	-.028	.000
Female	-1.811	.027	-.099	.000
Lower educated	-2.203	.064	-.081	.000
Middle educated	.163	.047	.008	.001
Employed part time	.374	.040	.014	.000
Household includes child(ren)	-.444	.030	-.024	.000
Household consists of couple	-.568	.029	-.031	.000
Public transportation	4.366	.043	.175	.000
Slow traffic	-10.818	.037	-.517	.000
N = 717				
R^2= .384				

The regression model for 2016/2017 shows that most independent variables are significant predictors at the 0.05 level. No significant relation has been found between commuting distance and the interaction variable low income * workplace location (p = .919). R^2 = .384, meaning that the independent variables predict 38.4% of the dependent variable commuting distance. Commuters travel .187 kilometre less for each kilometre that they reside further away from

Amsterdam CS. Moreover, commuters travel 1.614 kilometres more for each kilometre they work further away from the nearest intercity station. As mentioned above, not all the interaction variables are significant predictors of commuting distance. This is true when comparing the effect of residential location and workplace location between low income commuters and high income commuters. The effect on the commuting distance for residing one kilometre further away from Amsterdam CS or working one kilometre further away from the nearest intercity station is almost the same for people with a low income and people with a high income, where the commuting distance of high income persons increases .045 kilometre more than for low income households for each kilometre they work further away from Amsterdam CS. The increase in commuting distance for each kilometre further away from the nearest intercity station is the same for low income and high income persons. The commuting distance of middle income households increases by .280 kilometre for each kilometre they reside further away from Amsterdam CS, with the commuting distance decreases by .712 kilometre for each kilometre they work further away from the nearest intercity station.

Older people commute slightly shorter than younger people (.042 kilometre decrease per year of age). Females commute 1.811 kilometres less than males. Low educated people commute 2.203 kilometres less than high educated people, while middle educated people commute .163 kilometre more than high educated people. People that are employed part time commute .374 kilometre further than people that are employed full time. When a household consists of children then their commuting distance is .444 kilometres shorter than households without children. Couples commute .568 kilometres shorter than singles. People that commute by public transportation travel 4.366 kilometres more than those travelling by motorised vehicle, while people that travel by bicycle or by foot travel 10.818 kilometres less than those travelling with a motorised vehicle.

6 Conclusions, recommendations & discussion

This research was conducted to study the extent that residential and work locations of different income groups influence commuting duration and commuting distance. As a result it is possible to examine whether different income groups changed their residential and workplace locations. Moreover, it is possible to study whether these have had a positive or negative consequence for the different income groups. If for lower income groups a negative connection between living and/or working less central and their commute exists then the concerns expressed by non-scientific sources must be taken more seriously.

This chapter presents the conclusions (Section 5.1), recommendations for future research (Section 5.2) and discusses the findings in relation to other researches (Section 5.3). By doing to this research can be used by academics and policy makers to gain an insight into the connections amongst 1) residential location centrality and workplace location centrality (measured as the euclidean distance between the nearest intercity station and the 4-digit postal zone), 2) commuting duration and commuting distance, and 3) social equity amongst income groups.

6.1 Conclusions

Quantitative research was performed on commuting patterns in 2010/2011 and 2016/2017 , being the first and last years that the OViN survey was conducted. This thesis generally confirms the relations suggested in the conceptual framework. The degree of urbanisation was excluded because all people residing in or near Amsterdam reside in the highest degree of urbanisation. Respondents were divided into groups based on whether they live and/or work in Amsterdam, because of the existence of differences in personal preferences between these groups. The results indicate that between 2010/2011 and 2016/2017 the mean commuting duration increased.

People who reside in Amsterdam saw their commute lengthen by 0.5 minutes and 0.7 kilometres. The regression models show that people who live more central commute faster than people who live less central. Peoples' commuting distance shortens when they reside farther away from the city centre. However, in 2016/2017 the commuting duration increases when people live less central. Working farther away from the nearest intercity station leads to a lengthier commute in both 2010/2011 and 2016/2017.

Low income households have moved towards the city centre. Their residential location is on average 6.78 kilometres away from the city centre, while five years earlier the average distance was 7.33 kilometres. Still, low income households live farther away from the city centre than high income households. High income households, however, reside 6.44 kilometres away from the city centre. Hence, more high income households live more centrally than low income households. Middle income households moved farther away from the city centre. In fact, the mean distance between their residential location and the city centre is 7.20 kilometres. Five years earlier the mean distance was 6.80 kilometres. This means that middle income households live the farthest away from the city centre. The amount of low and middle income households declined, while the amount of high income households increased. This means that the influx of high income households were able to find housing nearer to the city centre at the cost of especially middle

income households that have to live farther away from the city centre, and less often live in Amsterdam.

By moving away from the city centre middle income households were not able to reduce their commuting duration and commuting distance. Both increase when they reside less central. in 2010/2011 middle income households commuted shorter when they reside farther away from the city centre. in 2016/2017 middle income households commute longer when they reside farther away from the city centre. It means that middle income households do not experience a better connection between the residential location and workplace location by moving away from the city centre. The increase in commuting duration and commuting distance is smaller than for low and high income households. The negative impact on living less central is smaller compared to low and high income households, but still existent.

Low income households, on the other hand, were able to improve their commute. By living more central low income households were able to improve their commutes. Moreover, the commuting duration and commuting distance in 2016/2017 is shorter for low income households than for high and middle income households. This was the opposite for 2010/2011. Especially the commuting duration has improved. Low income households that live more central commute faster than low income households that live less central.

People who live in Amsterdam but work outside Amsterdam commute longer when they reside less centrally in Amsterdam. The opposite is true for the centrality of the workplace location. Here, people who work not central outside Amsterdam commute shorter than people who work centrally outside Amsterdam. To conclude, when someone lives in Amsterdam but works outside Amsterdam then their commute is the shortest when they live central in Amsterdam, but work not central outside Amsterdam. People who do not live central in Amsterdam but work central outside Amsterdam experience the longest commutes.

People who reside outside Amsterdam saw their commute lengthen by 2.9 minutes and 4.6 kilometres. The split of low, middle and high income households outside Amsterdam remained stable. The commuting distance and commuting duration of people who reside outside Amsterdam increased. The commute of people who do not live central outside Amsterdam is shorter than for those residing central outside Amsterdam. The same is true for peoples' commuting duration.

6.2 Discussion

The outcomes of this thesis complements to the knowledge on the extent of which peoples' residential location and workplace location affect commuting durations and commuting distances. Furthermore, it adds to the ongoing worldwide debate on social equity issues between income groups in regard to the afore-mentioned relation.

The complexity of studying commuting behaviour already came to the fore in the literature study. Not only the socio-demographic background of sample group, but also the spatial context of the case study area affects commuting decisions and commuting options (Axisa et al., 2012; Jun, 2020). Moreover, personal preferences of individuals make it more difficult to predict their commute. People who live in different areas are fundamentally different to each other. As a result,

various studies have shown different results on the influence of the socio-demographic and spatial variables that were applied in this research. In this report these variables have proven to better predict commuting duration than commuting distance. This makes sense, because peoples commuting duration is composed by both travel distance and travel speed. Overall, this report largely coincides with other authors in regard to the influence of the variables *gender, age, employment, household composition, highest completed education, household income* and *main mode of transport*.

A fundamental question that this thesis examined is whether the commute of low income groups lengthens as a result of rising house prices, and as a result is an example of growing social inequity. According to numerous authors low income households are being pushed to the urban fringe or to nearby agglomerations such as Almere, while high income households would reside more central in Amsterdam. This research found no evidence on the existence of this particular concern. In fact, low income households have improved their commute in comparison to high income households. The research, however, did find evidence that 1) middle income households now reside farther away from Amsterdam CS than low and high income households, and 2) the commute of middle income households increases more than the commute of low and high income households when they reside less central. Historically Amsterdam has had a relatively small housing stock of intermediate housing and a larger than usual housing stock of social housing (Berkers & Dignum, 2018; Savini et al., 2015). Because owner-occupied house values have risen since 2013 (Van den Eerenbeemt, 2017) middle income households that cannot make use of social housing opportunities now are unable to buy or rent in the intermediate housing segment. As a result middle income households are affected to a bigger extent than low income households who are eligible for a bigger housing stock than middle income households. Middle income households experience diminishing opportunities to live in city centres, which impacts their lives because they have to spend more time and budget on travelling to and from their residential location. This is not a problem if these middle income households voluntarily make the decision to live outside Amsterdam or not central in Amsterdam because of their personal preferences. However, when people forcefully reside outside Amsterdam or not central in Amsterdam then their quality of life is likely to be reduced.

Hitherto many authors have written about the increasing pressure on Amsterdam's housing market and the possible consequences on the quality of life with a dominant focus on low income households. Given the findings described in this report a new debate could arise in which not the worsening opportunities of low income households should be prioritised, but instead should give way to the worsening conditions of middle income households.

6.3 Recommendations

Due to the complexity of commuting behaviour it may be difficult for local and regional policy makers in Amsterdam to apply the existing literature into the spatial context of Amsterdam. Because this thesis specifies to the municipality of Amsterdam it provides a detailed view on the extent of which changes in peoples' residential and workplace locations affects their commuting behaviour, given the spatial context of Amsterdam as well as the socio-demographic background of its citizens.

Part of why commuting behaviour is complex is because of personal preferences that individuals have. This research limits itself by not having information about personal preferences. Therefore the assumption was made that every respondent that lives in Amsterdam choses to do so. This assumption cannot be made for respondents living elsewhere, because they may not want to live in a dense urban area. The regression models could only be calculated for people that live in Amsterdam as a result. Future research could integrate personal preferences of citizens while examining the extent of which residential and workplace locations affect commuting duration and commuting distance. One way to do so is by using the same sample group over a period of time instead of using the repeated cross-section technique. Because each individual has their own preferences certain assumptions must be made on why people make certain decisions in their commuting behaviour. By using the same sample group qualitative research methods such as interviews can be used to determine differences in, and the influence of personal preferences amidst individuals.

This thesis investigated to what extent changes in residential and workplace locations affects peoples' commuting duration and distance over a timespan of approximately five years. A larger amount of years between the two samples could be beneficial for this type of research, because it is likely that changes in where social groups reside and work take more time. The OViN survey was initiated in 2010 and replaced in 2017, which meant that it was not possible to extent the amount of years between the datasets. Because property values increased after the financial crisis, which ended in 2010, this thesis concerned changes as a result of this rising property values. Moreover, by using these datasets this thesis focused primarily on socio-demographic determinants. By using data prior to the financial crisis changes in the spatial context and decisions in land-use planning could come to the fore.

References

AdminStat (n.d.) MAps, analysis and statistics about the resident population. Modena, Italy: Urbistat. Retrieved on 14 September, 2020, from: https://ugeo.urbistat.com/AdminStat/en/nl/demografia/eta/amsterdam/23055764/4.

Amsterdam Economic Board (2017). Woon-werk verkeer (pendelstromen) in de Metropoolregio Amsterdam. Retrieved on April 27, 2020, from: https://amsterdameconomicboard.com/scenario/dagelijks-pendelen-er-341-duizend-inwoners-regios-naar-metropoolregio-amsterdam-om-gaan-werken.

Anas, A., Arnott, R. & Small, K.A. (1998). Urban spatial structure. Journal of Economic Literature, 36 (3), pp. 1426-1464. Cities, 98, 102587.

Axisa, J.J., Scott, D.S. & Newbold, K.B. (2012). Factors influencing commute distance: a case study of Toronto's commuter shed. Journal of Transport Geography 24, pp. 123-129.

Ben-Elia, E., Ettema, D. (2011). Changing commuters' behavior using rewards: a study of rush-hour avoidance. Transport Research Part F: Traffic Psychology and Behaviour, vol. 14, issue 5, pp. 354-368.

Berkers, V. & Dignum, K. (February 2018). Wonen in Amsterdam 2017 woningmarkt. Municipality of Amsterdam, Afdeling Wonen.

Burger, M.J. (2011). Structure and Cooptition in urban networks. Rotterdam: Erasmus Research Institute of Management.

CBS (Juni 2016). Hoogopgeleide man maakt de meeste woon-werkkilometers. Centraal Bureau voor de Statistiek. Retrieved on 3 June, 2019, from: https://www.cbs.nl/nl-nl/nieuws/2016/25/hoogopgeleide-man-maakt-de-meeste-woon-werkkilometers.

CBS (n.d.a). Onderweg in Nederland. Centraal Bureau voor de Statistiek. Retrieved on 25 January, 2020, from: https://www.cbs.nl/nl-nl/deelnemers-enquetes/deelnemers-enquetes/personen/onderzoek/lopend/onderweg-in-nederland.

CBS (n.d.b). Werkenden. Centraal Bureau voor de Statistiek. Retrieved on 23 August, 2020, from: https://www.cbs.nl/nl-nl/visualisaties/dashboard-arbeidsmarkt/werkenden.

CBS (n.d.c). Codeboek OViN 2017. Centraal Bureau voor de Statistiek.

Champion, T., Coombes, M. & Brown, D., (2008). Migration and longer distance commuting in rural England. Regional Studies 42, pp. 1-15.

Chatterjee, K., Clark, B., Martin, A. & Davis, A. (2017). The Commuting and Wellbeing Study: Understanding the Impact of Commuting on People's Lives. Bristol: UWE.

Clark, W., Huang, Y. & Withers, S. (2003). Does commuting distance matter? Commuting tolerance and residential change. Regional Science and Urban Economics, 33, pp. 199-221.

Clark, B., Chatterjee, K. & Melia, S. (2016). Changes to commute mode: The role of life events, spatial context and environmental attitude. Transportation Research Part A, vol. 89, pp. 89-105.

Coombs, M. & Raybould, A. (2001). Commuting in England and Wales: "people" and "place" factors.

Couzy, M. (2018). Kwart van Amsterdam verdient twee keer modaal. Amsterdam: Het Parool. Retrieved on 23 August, 2020, from: https://www.parool.nl/nieuws/kwart-van-amsterdam-verdient-twee-keer-modaal~b4e3e49f/.

Couzy, M. (2020). Voor corona stegen de huizenprijzen nog in Amsterdam. Amsterdam: Het Parool. Retrieved on April 27, 2020, from: https://www.parool.nl/amsterdam/voor-corona-stegen-de-huizenprijzen-nog-in-amsterdam~bbb1e9cf/.

CROW (n.d.). Informatie over het gebruik van het openbaar vervoer in Nederland en de modal split. Kennisplatform CROW. Retrieved on 3 November, 2020, from: https://www.crow.nl/duurzame-mobiliteit/home/systeemintegratie/openbaar-vervoer/gebruik-ov.

CROW (2016). Man zit het meest aan het stuur. Kennisplatform CROW. Retrieved on 11 July, 2019, from: https://www.crow.nl/mobiliteit-en-gedrag/nieuws-mobiliteit-en-gedrag/juni-2016/man-zit-het-meest-aan-het-stuur.

Dargay, J. & Van Ommeren, J. (2005). The effect of income on commuting time - an analysis based on panel data. Amsterdam: European Regional Science Association.

De Jong, I., Van Oosteren, C. & Slot, J. (2013). Laagopgeleiden op de arbeidsmarkt in de Metropoolregio Amsterdam. Municipality of Amsterdam, Bureau Onderzoek en Statistiek.

Dirks, B. (September 2017). Amsterdamse wethouder Ivens: 'De wachttijd voor een huurwoning is bizar'. De volkskrant. Retrieved on 4 July, 2019, from: https://www.volkskrant.nl/nieuws-achtergrond/amsterdamse-wethouder-ivens-de-wachttijd-voor-een-huurwoning-is-bizar~be956614/?referer=https%3A%2F%2Fwww.google.nl%2F.

European Commission (n.d.). Urban property: prices, ownership and occupancy. Retrieved on 28 February, 2020, from: https://urban.jrc.ec.europa.eu/thefutureofcities/affordable-housing#the-chapter.

Filipi, G. (2014). Albania commuting from home to work. Tirania: Instituti i Statistikave.

Gardner, B. (2009). Modelling motivation and habit in stable travel mode contexts. Transportation Research Part F: Traffic Psychology and Behaviour, vol. 12, issue 1, pp. 68-76.

Gordon, P., Kumar, A. & Richardson, H.W. (1989). Congestion, changing metropolitan structure and city size in the United States. International Regional Science Review, 12, pp. 45-56.

Green, A. (1999). Employment opportunities and constraints facing in-migrants to rural areas in England. Geography, 84, pp. 34-44.

Heinen, E., Panter, J., Mackett, R., Ogilvie, D. (2015). Changes in mode of travel to work: a natural experimental study of new transport infrastructure. International Journal Behavioural Nutrition and Physical Activity, vol. 12, issue 1, pp. 81.

Hekwolter of Hekhuis, M., Nijskens, R. & Heeringa, W. (2017). The housing market in major Dutch cities. Amsterdam: De Nederlandse Bank N.V.

Horner, M.W. (2004). Spatial dimensions of urban commuting: a review of major issues and their implications for future geographic research. The professional Geographer 56(2), p.p. 160-173.

Jun, M. (2020). The effects of polycentric evolution on commute times in a polycentric compact city: A case of the Seoul Metropolitan Area.

Kellett, J., Morrissey, J. & Karuppannan, S. (2016). Drive till you qualify: an alternative view of housing affordability. SOAC 7 Conference Proceedings, p.p. 1-9.

Khaddari, R. (2020). Op jacht naar een huurhuis in Amsterdam: 'Er is niets over van mijn wensenlijst'. Het Parool. Retrieved on April 27, 2020, from: https://www.parool.nl/ps/op-jacht-naar-een-huurhuis-in-amsterdam-er-is-niets-over-van-mijn-wensenlijst~bdc0fca5/.

Kieft, S. & Grooten, J. (2015). Regionale verdichting en gebruik OViN voor toepassen in de Metropoolregio en Gemeente Amsterdam. OViN Symposium 2015.

Liu, X., Gao, L., Ni, A. & Ye, N. (2020). Understanding better the influential factors of commuters' multi-day travel behavior: Evidence from Shanghai, China. Sustainability, 12, 376.

Lyons, G. & Chatterjee, K. (2008). A human perspective on the daily commute: costs, benefits and trade-offs. Transport Reviews, 28(2), pp 181-198.

Mason, V.A. (2005). Changing Commute Distances. Bristol: UWE.

Mårtensson, J. (2015). Social and economic effects of commuting: a case study on commuting households within Umea enlarged local labour market region. Umea University.

Mee, R.W. & Chua, T.C. (1991). Regression toward the mean and the paired sample t test. The American Statistician, 45(1), pp 39-42.

Möhlmann, J., Weijschede-Van der Straaten, W. & Rouwendal, J. (2013). Why are the commuting distances of highly educated couples so short? An analysis of the heterogeneity of the location preferences of households. The Hague: RSA Voorjaarsdag.

Municipality of Amsterdam (2013). Amsterdam Aantrekkelijk Bereikbaar, MobiliteitsAanpak Amsterdam 2030.

Municipality of Amsterdam (2019). Amsterdamse Thermometer van de Bereikbaarheid 2019. Amsterdam: Municipality of Amsterdam, section Traffic & public space.

Municipality of Amsterdam (2020). Kerncijfers Amsterdam 2020. Amsterdam: Municipality of Amsterdam, section Research, information and statistics.

Nu.nl (2017). Inkomensgroei Amsterdam ongelijk, 'arme' inwoners naar rand van stad. Retrieved on 11 July, 2019, from: https://www.nu.nl/amsterdam/4860021/inkomensgroei-amsterdam-ongelijk-
arme-inwoners-rand-van-stad.html.

Oakil, A., Ettema, D., Arentze, T., Timmermans, H. (2011). A longitudinal analysis of the dependence of commute mode switching decisions on mobility decisions and life-cycle events. Hong Kong: 16th International Conference of Hong Kong Society for Transportation Studies.

Olde Kalter, M. J., Bakker, P. & Jorritsma, P. (2010). Woon-werkverkeer als drijvende kracht achter groei automobiliteit. Roermond: Colloquium Vervoersplanologisch Speurwerk.

Omroepflevoland.nl (2020). 'Woon-werkverkeer naar Amsterdam moet omlaag'. Almere: Omroep Flevoland. Retrieved on April 27, 2020, from: https://www.omroepflevoland.nl/nieuws/179678/woon-werkverkeer-naar-amsterdam-moet-omlaag.

Oozo.nl (n.d.). Wetenswaardigheden, cijfers en statistieken over Amsterdam. Retrieved on 23 August, 2020, from: https://www.oozo.nl/cijfers/amsterdam.

Östh, J. & Lindgren, U. (2012). Do changes in GDP influence commuting distances? A study of Swedish commuting patterns between 1990 and 2006. Tijdschrift voor Economische and Social Geografie, 103(4), pp 443-456.

Panter, J., Griffin, S., Dalton, A.M. & Ogilvie, D. (2013). Patterns and predictors of changes in active commuting over 12 months. Preventive Medicine, vol. 57, issue 6, pp. 776-784.

Plotts, T. (2011). A multiple regression analysis of factors concerning superintendent longevity and continuity relative to student achievement. South Orange, NJ, USA: Seton Hall University.

Province of North Holland (n.d.). Gemiddeld besteedbaar inkomen. Retrieved on 23 August, 2020, from: https://cijfers.noord-holland.nl/dashboard/gemiddeld-besteedbaar-inkomen.

Raets, B. (September 2005). Wonen aan de rand. CBS-webmagazine.

Remie, M. (April 2016). Straks wonen alleen nog de rijken in de stad. NRC. Retrieved on 6 July, 2019, from: https://www.nrc.nl/nieuws/2016/04/19/straks-wonen-alleen-nog-de-rijken-in-

de-stad-
1610078-a1032373.

Rijkswaterstaat.nl (n.d.). A10 betere bereikbaarheid zuidasdok en noordelijke randstad. Doelen en resultaten. Rijkswaterstaat. Retrieved on 9 July, 2019, from: https://www.rijkswaterstaat.nl/wegen/projectenoverzicht/a10-betere-bereikbaarheid-zuidasdok-en-noordelijke-randstad/doelen-en-resultaten/index.aspx.

Ritsema van Eck, J. & Hilbers, H. (November 2018). De ene forens is de andere niet: een analyse van twee decennia woonwerkverplaatsingen. Planbureau voor de Leefomgeving.

RTLZ.nl (2020). Amsterdammer doet er langer over dan Londenaar om op z'n werk te komen. Retrieved on April 27, 2020, from: https://www.rtlz.nl/life/carriere/artikel/5022851/amsterdam-londen-reistijd-woon-werkverkeer-europa-steden-files.

Sandag (n.d.). San Diego Association of Governments. Chapter 6: Social Equity & Environmental Justice Assessment, Fair Planning and Development for all Communities. Retrieved on 8 May, 2019, from: https://www.sandag.org/rcp_revised_draft/chapter6.pdf.

Sandow, E. & Westin, K. (2010). The persevering commuter - Duration of long-distance commuting. Transportation research part A: policy and practise, 44 (6), pp. 433-445.

Schroten, A., Otten, M., 't Hoen, M., Van Essen, H., De Wilde, H., Uyterlinde, M., Wilmink, I. & Cuelenaere, R. (2014). CO2-reductie door gedragsverandering in de verkeerssector. Delft: CE Delft.

Schwanen, T. & Dijst, M. (2002). Travel-time ratios for visits to the workplace: the relationship between commuting time and work duration. Transportation Research Part A: Policy and Practise, 36 (7), pp. 573-592.

Schwanen, T., Dieleman, F.M. & Dijst, M. (2004). The impact of metropolitan structure on commute behavior in the Netherlands: a multilevel approach. Growth and Change, 35 (3), pp. 304-333.

Schwanen, T. (2002). Urban form and commuting behaviour: A cross-European perspective. Tijdschrift voor Economische en Sociale Geografie, 9, pp.173-186.

Sedghi, A., (July 2015). Young people are driving the 'urban renaissance' of city centres - report. Retrieved on 3 November, 2019, from: https://www.theguardian.com/cities/datablog/2015/jul/22/young-people-urban-renaissance-city-centres-millennials-report. UK: The Guardian.

Shen, Q. (2007). Spatial and social dimensions of commuting. Journal of the American Planning Association, 66 (1), pp. 68-82.

Statistics Canada (2006). General Social Survey: Commuting Times. Ottawa: Statistics Canada Retrieved on 15 February, 2020, from: http://www.statcan.gc.ca/daily-quotidien/060712/dq060712b-eng.htm.

Statistics Canada (2007). Portrait of the Canadian Population in 2006: Subprovincial Population Dynamics. Ottawa: Statistics Canada.

Synchroon (Augustus 2018). Stationsgebieden in ontwikkeling. Synchroon Ontwikkelaars. Retrieved on 10 July, 2019, from: https://synchroon.nl/inspiratie/stationsgebieden-in-ontwikkeling/.

Thørgersen, J. (2006). Understanding repetitive travel mode choices in a stable context: a panel study approach. Transportation Research Part A: Policy and Practice, vol. 40, pp. 621–638.

Tordoir, P., Poorthuis, A. & Renooy, P. (2015). De veranderende geografie van Nederland, opgaven op mesoniveau. Amsterdam: Regioplan.

UBS (2018). Global real estate bubble index 2018. Retrieved on 3 March, 2020, from: https://www.ubs.com/global/en/wealth-management/chief-investmentoffice/our-research/life-goals/2018/global-real-estate-bubble-index-2018.html.

Van de Coevering, P.P. (2012). De potentie van longitudinaal onderzoek voor een robuuste onderbouwing van ruimtelijk mobiliteitsbeleid. Amsterdam: CVS bijdragen van deelnemers.

Van den Berg, G.J. & Gorter, C. (2012). Job search and commuting time. Journal of Business & Economic Statistics, vol. 15, issue 2.

Van den Eerenbeemt, M. (2017a). Huizenprijzen 9,7 Procent Hoger in Vergelijking met Vorig Jaar; Vooral Prijsstijging in Grote Steden. De Volkskrant. Retrieved on 4 July, 2019, from: https://www.volkskrant.nl/economie/huizenprijzen-9-7-procent-hoger-in-vergelijking-met-vorig-jaarvooral-prijsstijging-in-grote-steden~a4521357/.

Van den Eerenbeemt, M. (2017b). Zijn de Amsterdamse huizenprijzen over hun hoogtepunt heen? De Volkskrant. Retrieved on 8 September, 2019, from: https://www.volkskrant.nl/economie/zijn-de-amsterdamse-huizenprijzen-over-hun-hoogtepunt-heen~bc0033ff/.

Van der Laan, L., Vogelzang, J. & Schalke, R. (1998). Commuting in multi-nodal urban systems: an empirical comparison of three alternative models. Oxford: Tijdschrijft voor economische en sociale geografie 89(4), p.p. 384-400.

Van Middelkoop, M. & Schilder, F. (2017). Middeninkomens op de woningmarkt, ruimte op een krap speelveld. Den Haag: Planbureau voor de Leefomgeving.

Van Ommeren, J., Van den Berg, G.J. & Gorter, C. (2002). Estimating the marginal willingness to pay for commuting. Journal of regional science, vol. 40, issue 3, pp. 541-563.

Van Wee, B. (2011) Evaluating the impact of land use on travel behaviour: the environment versus accessibility. Transport Geography 19, pp. 1530-1533.

Van Wee, B., Annema, J.A. & Banister, D. (2013). The Transport System and Transport Policy, An Introduction.

Verplanken, B., Walker, L., Davis, A., Jurasek, M. (2008). Context change and travel mode choice: combining the habit discontinuity and self-activati on hypotheses. Journal of Environmental Psychology, volume 28, issue 2, pp. 121-127.

Visser, M. (2017). Helft van de Amsterdamse stellen is hoogopgeleid. Amsterdam: Het Parool. Retrieved on 23 August, 2020, from: https://www.parool.nl/nieuws/helft-van-de-amsterdamse-stellen-is-hoogopgeleid~b02cd544/#:~:text=In%20Amsterdam%20is%2054%20procent,hbo%2D%20of%20een%20wetenschappelijke%20opleiding.

VPRO Tegenlicht. (2017). City for Sale. VPRO Tegenlicht. Retrieved from https://www.vpro.nl/programmas/tegenlicht/kijk/afleveringen/2017-2018/city-for-sale.html?.

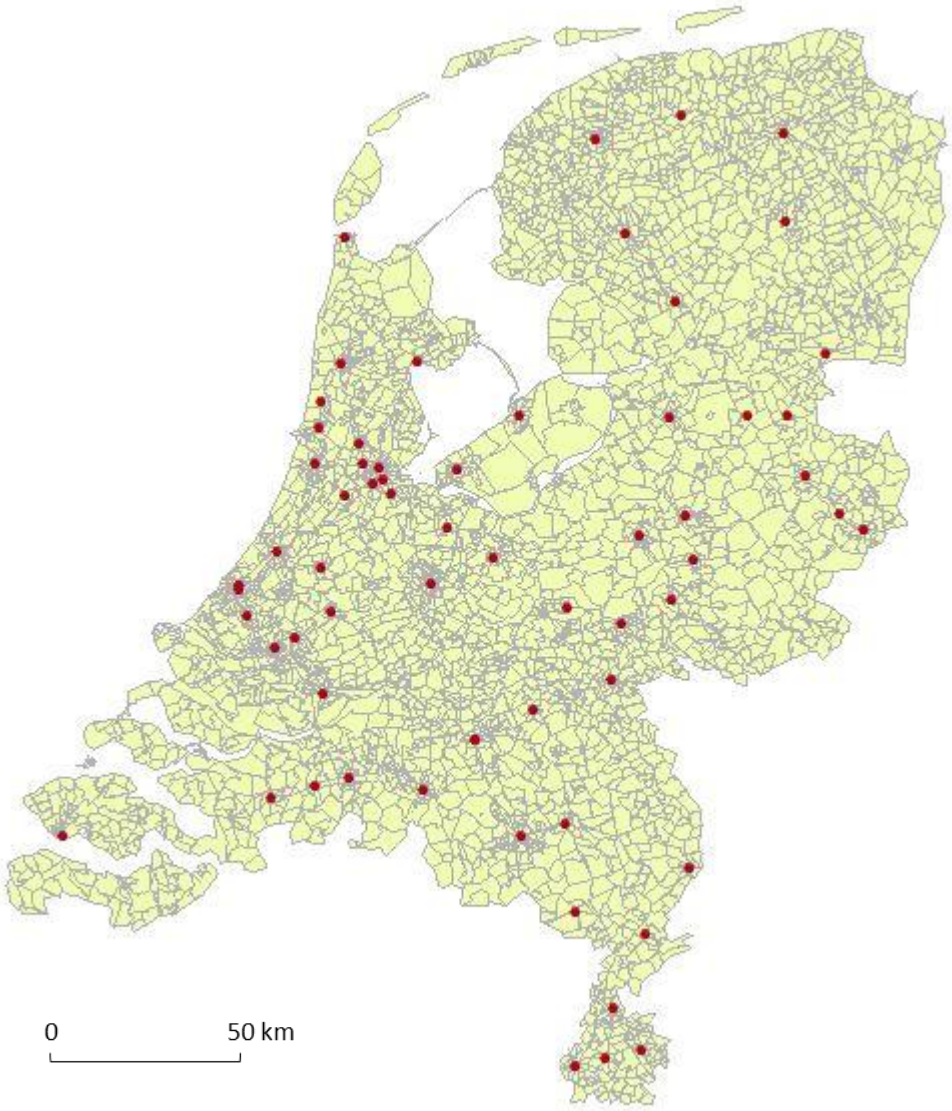
Wolla, S.A. & Sullivan, J. (2017). Education, income and Wealth. Federal Reserve Bank of St. Louis.

Ye, R & Titheridge, H. (2017). Satisfaction with the commute: the role of travel mode choice, built environment and attitudes. Transportation Research Part D: Transport and Environment, 52 (Part B), pp. 535-547.

Zhao, J., Bentlage, M. & Thierstein, A. (2016). 'Knowledge-Workers': A Conceptual Framework on Commuting Patterns. Wiesbaden: Springer Fachmedien.

Appendixes

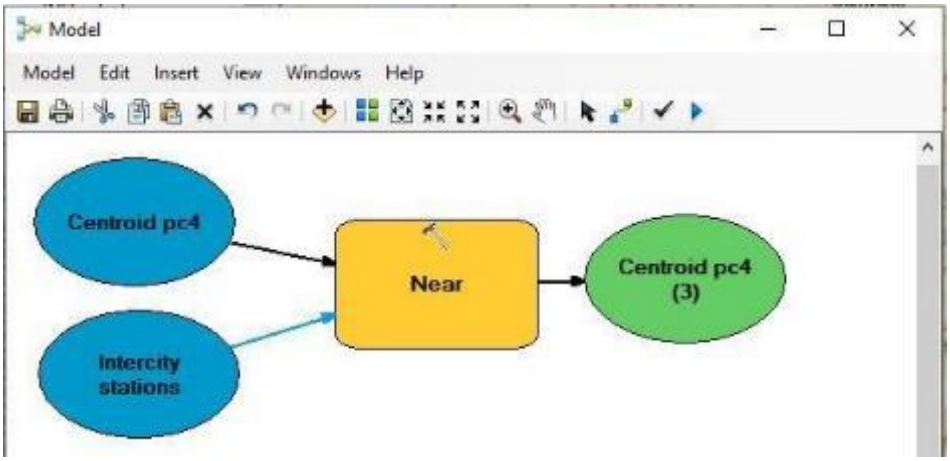
Appendix I: Intercity stations in the Netherlands



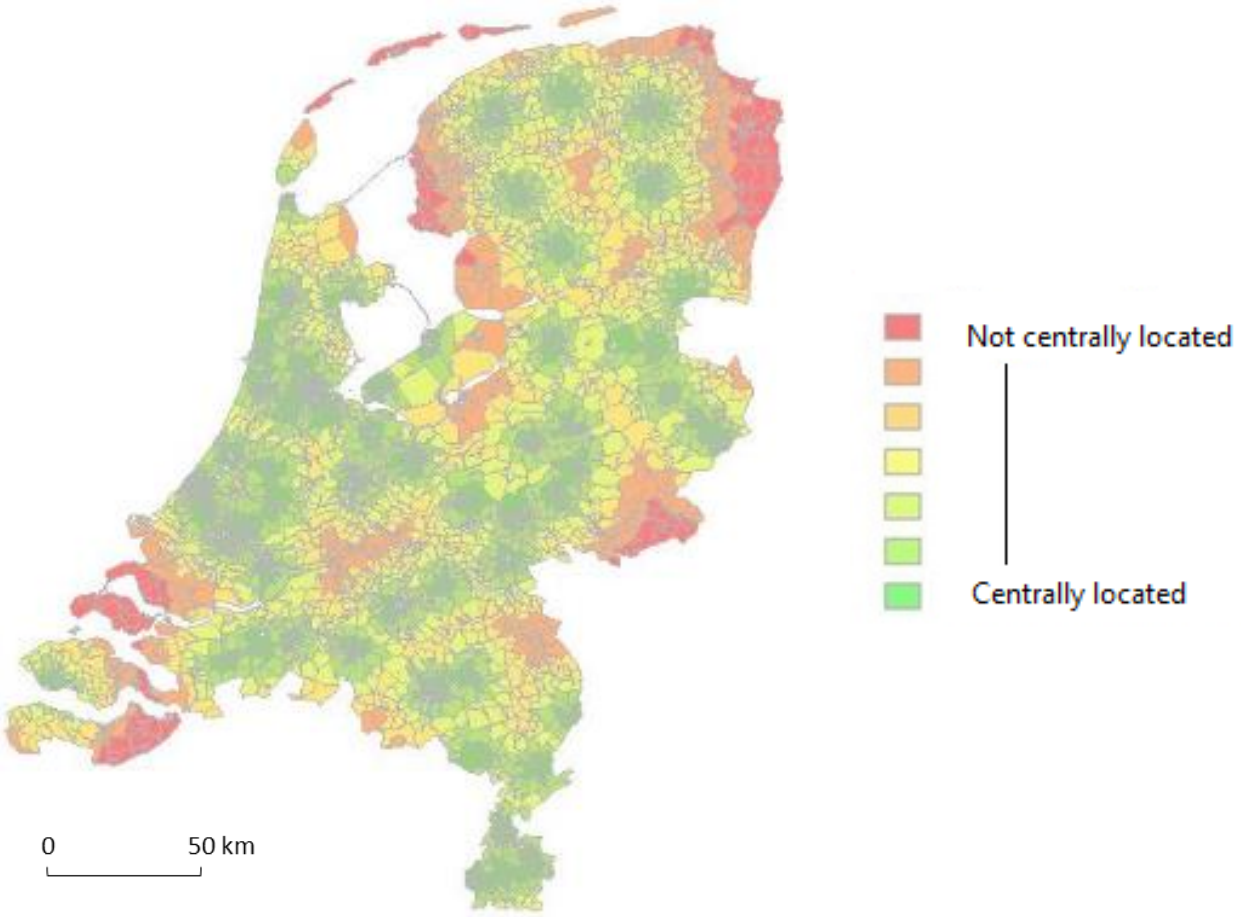
Note: red dots are Intercity stations (IC stations).

Appendix II: Centrality

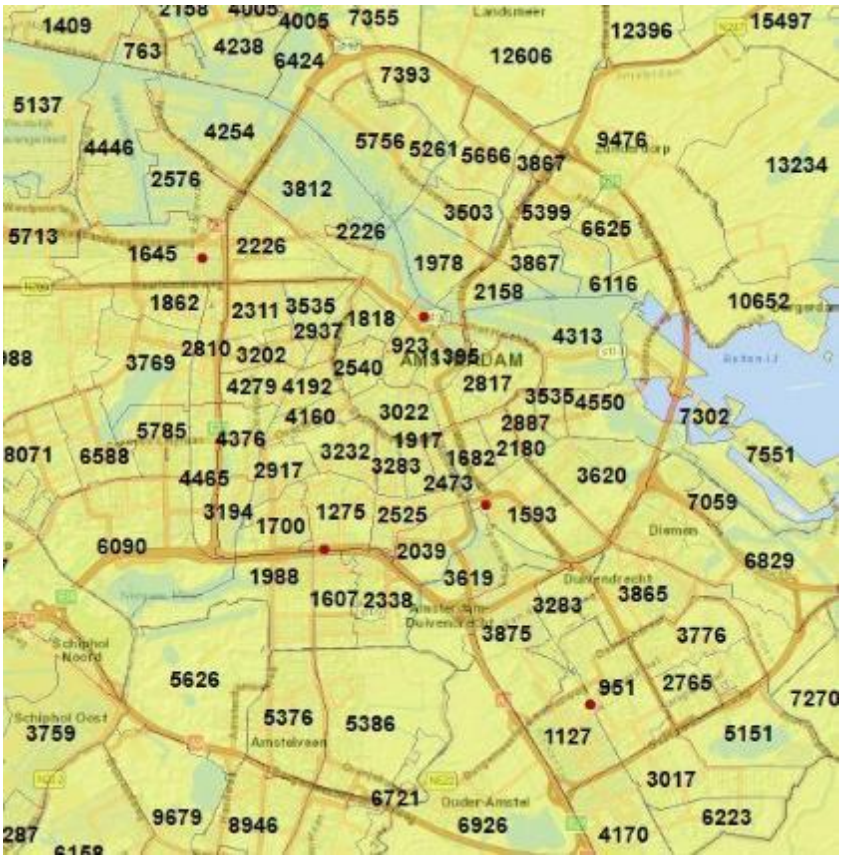
Near tool in ArcGIS:



Centrality map per 4-digit postal zone:



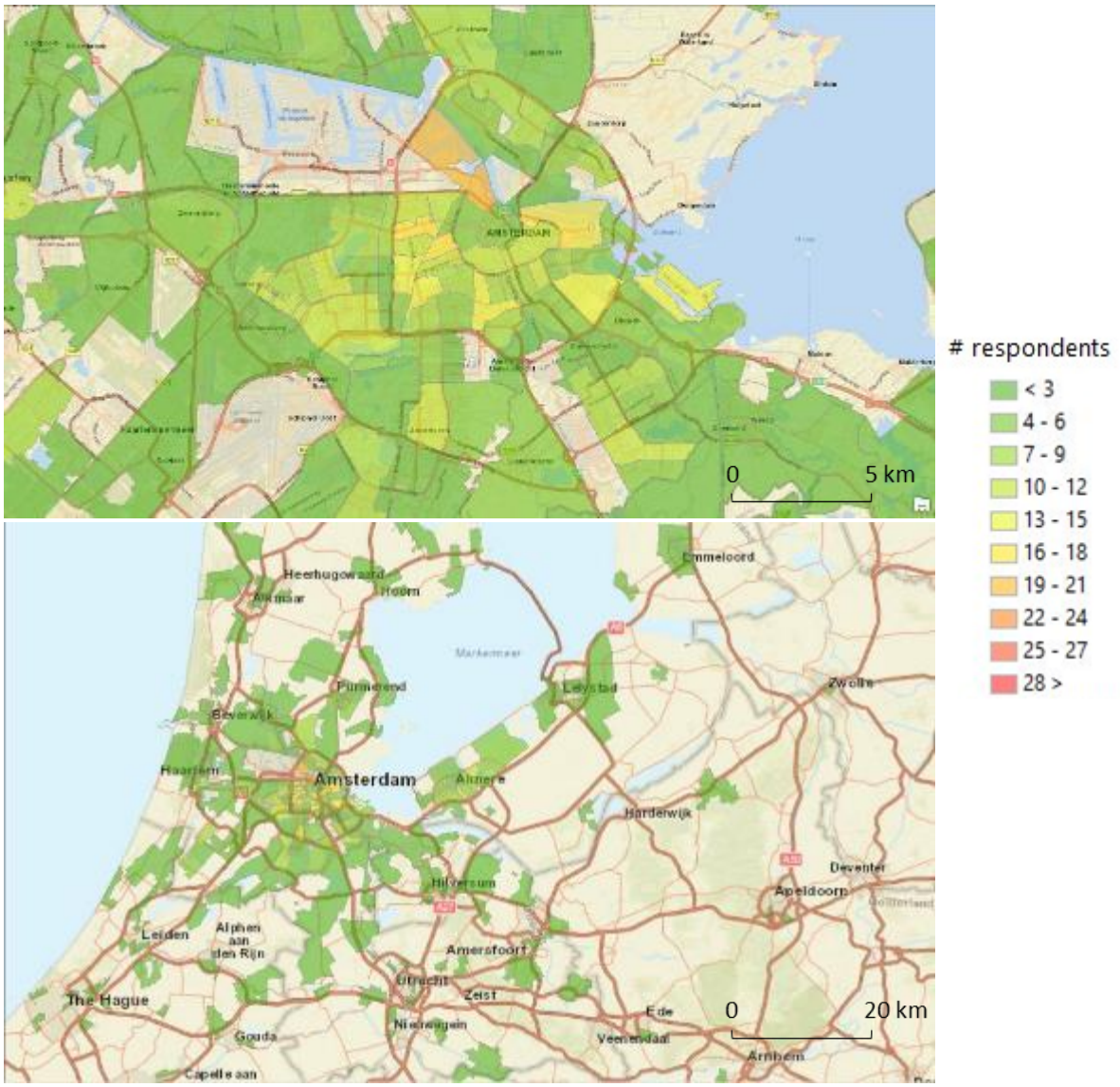
Centrality per 4-digit postal zone with numbers for the Amsterdam region:



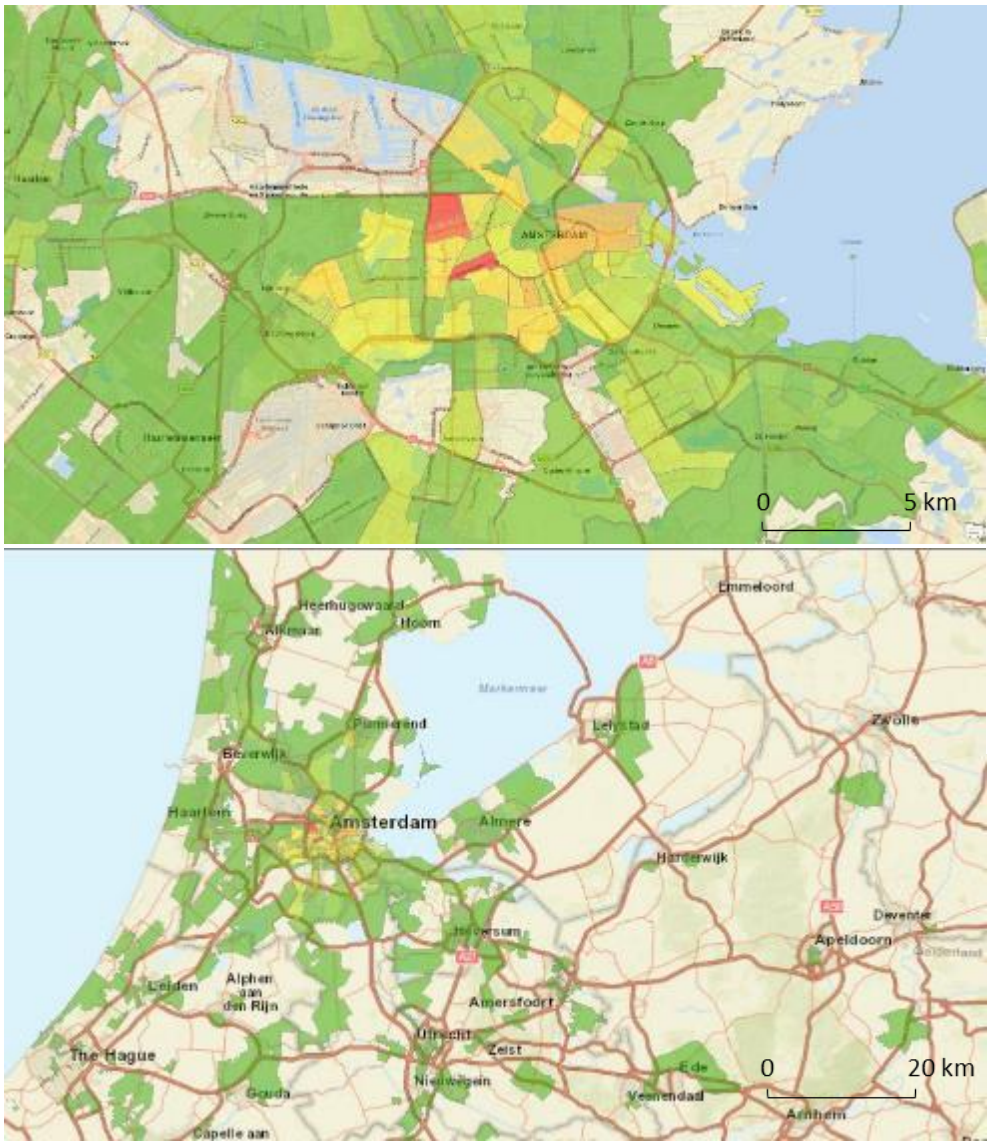
Appendix III: Spatial analysis maps

Residential location of the respondents (without weight factor)

2010/2011

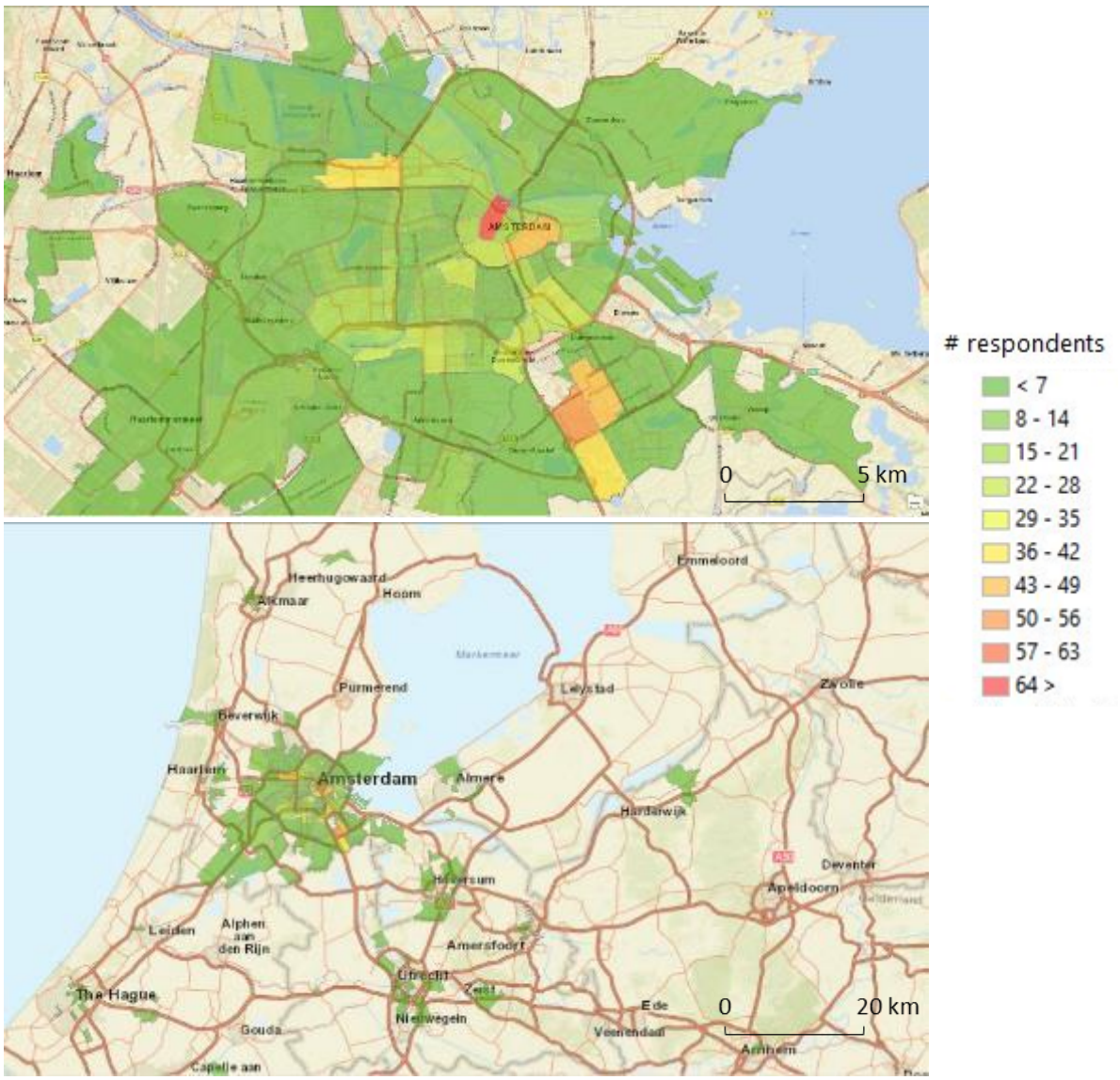


2016/2017

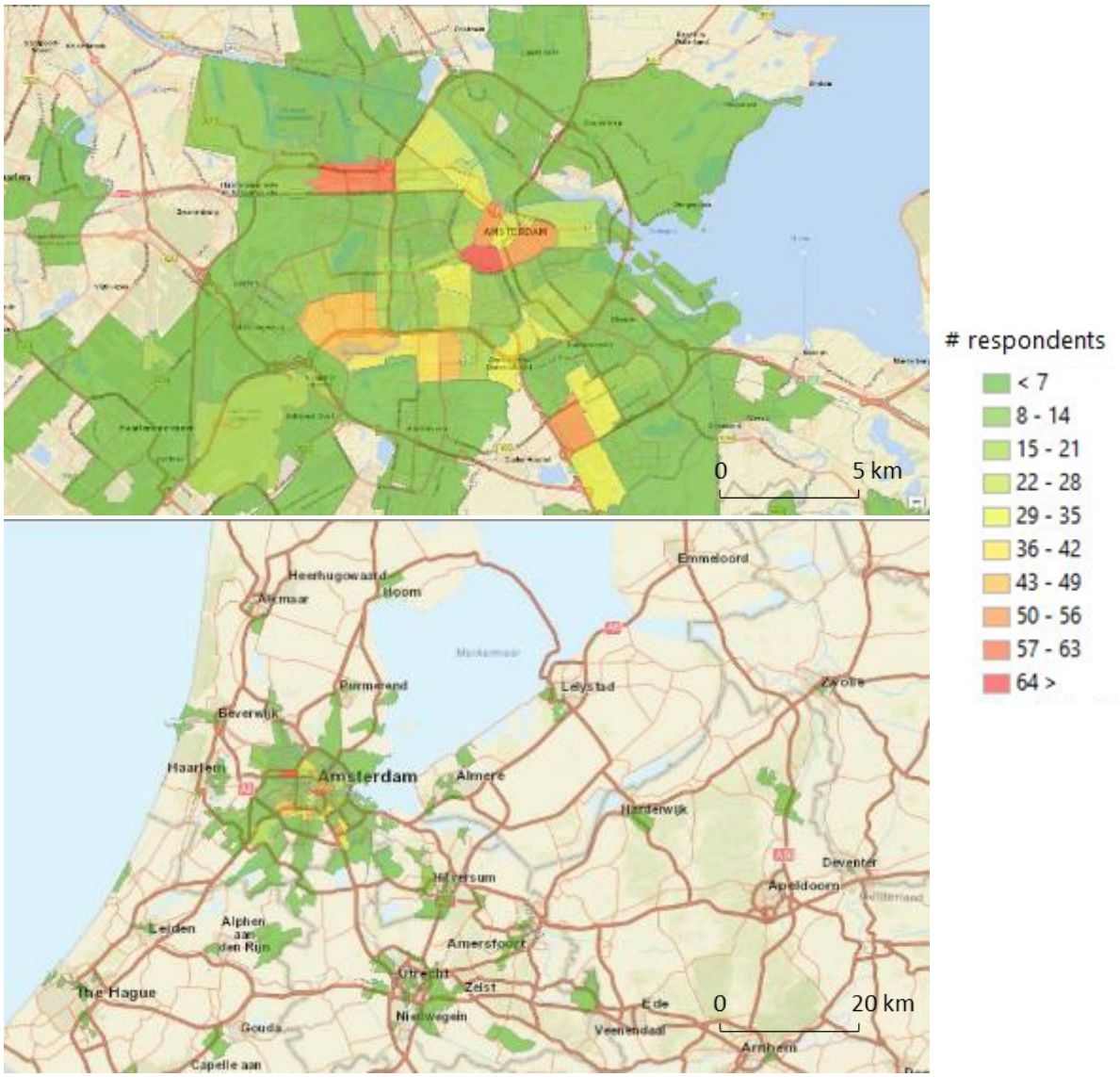

0
5 km
Amsterdam
Haarlem
Almere
Lelystad
Zwolle
Emmeloord
Harderwijk
Apeldoorn
Deventer
Amersfoort
Utrecht
Zeist
Leiden
The Hague
Gouda
Veenendaal
Arnhem
0
20 km
respondents
< 3
4 - 6
7 - 9
10 - 12
13 - 15
16 - 18
19 - 21
22 - 24
25 - 27
28 >

Workplace location of the respondents (without weight factor)

2010/2011

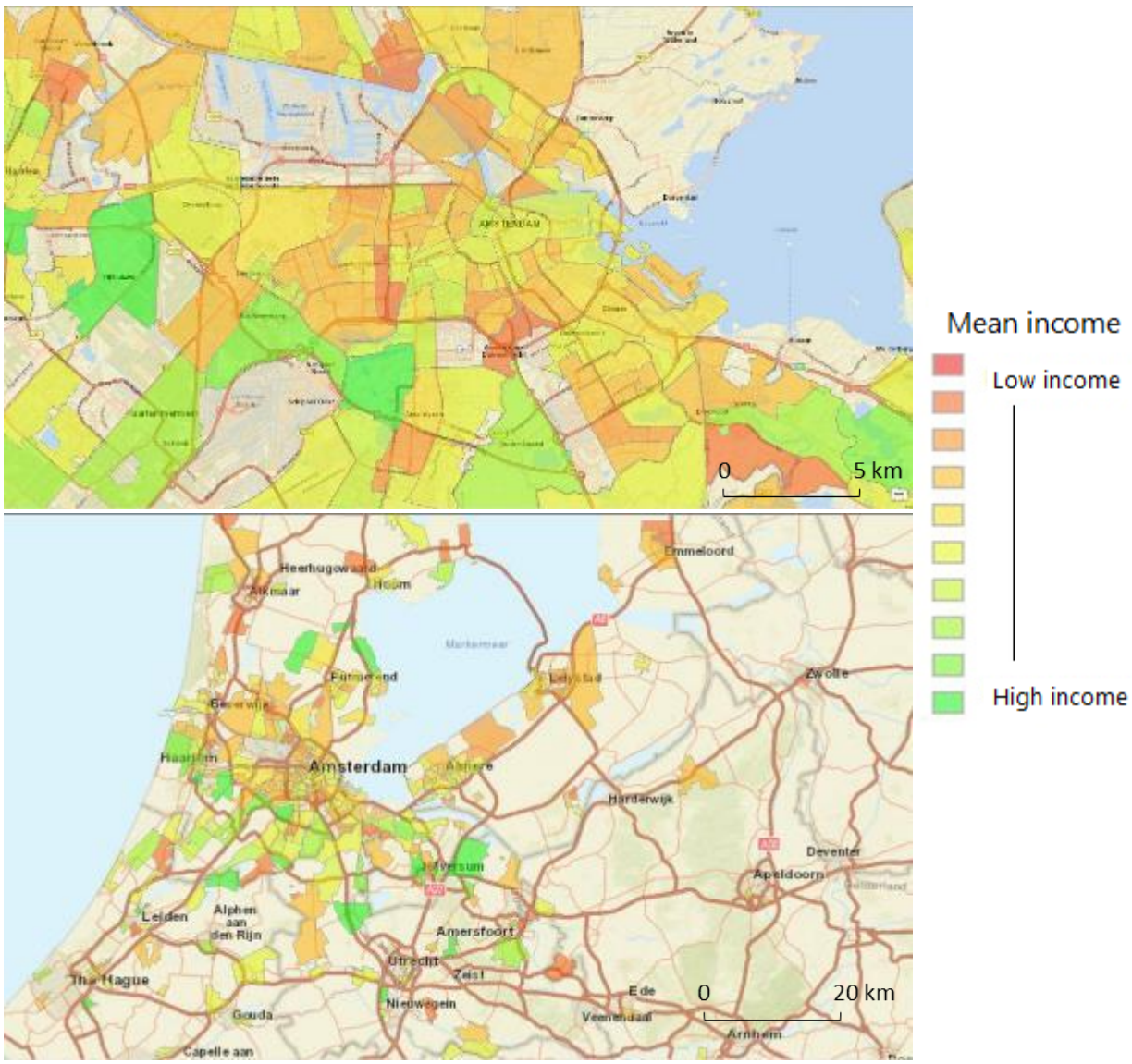


2016/2017

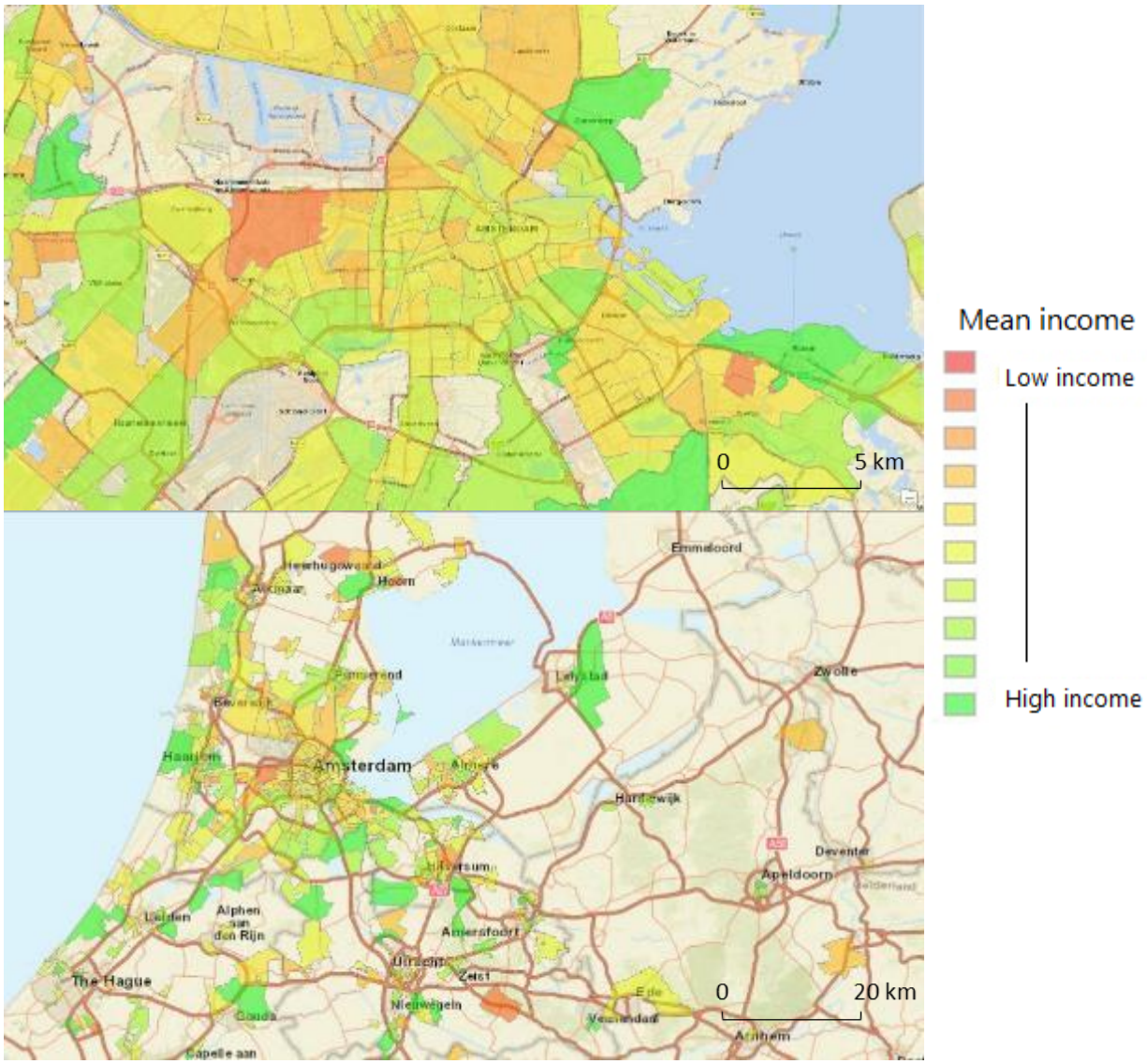

AMSTERDAM
0
5 km
Heerhugowaard
Alkmaar
Hoorn
Purmerend
Beverwijk
Haarlem
Amsterdam
Almere
Lelystad
Emmeloord
Zwolle
Harderwijk
Hilversum
Apeldoorn
Deventer
Leiden
Alphen aan den Rijn
Amersfoort
Utrecht
Zeist
The Hague
Gouda
Nieuwegein
Ede
Veenendaal
Arnhem
Capelle aan
0
20 km
respondents
< 7
8 - 14
15 - 21
22 - 28
29 - 35
36 - 42
43 - 49
50 - 56
57 - 63
64 >

Mean income

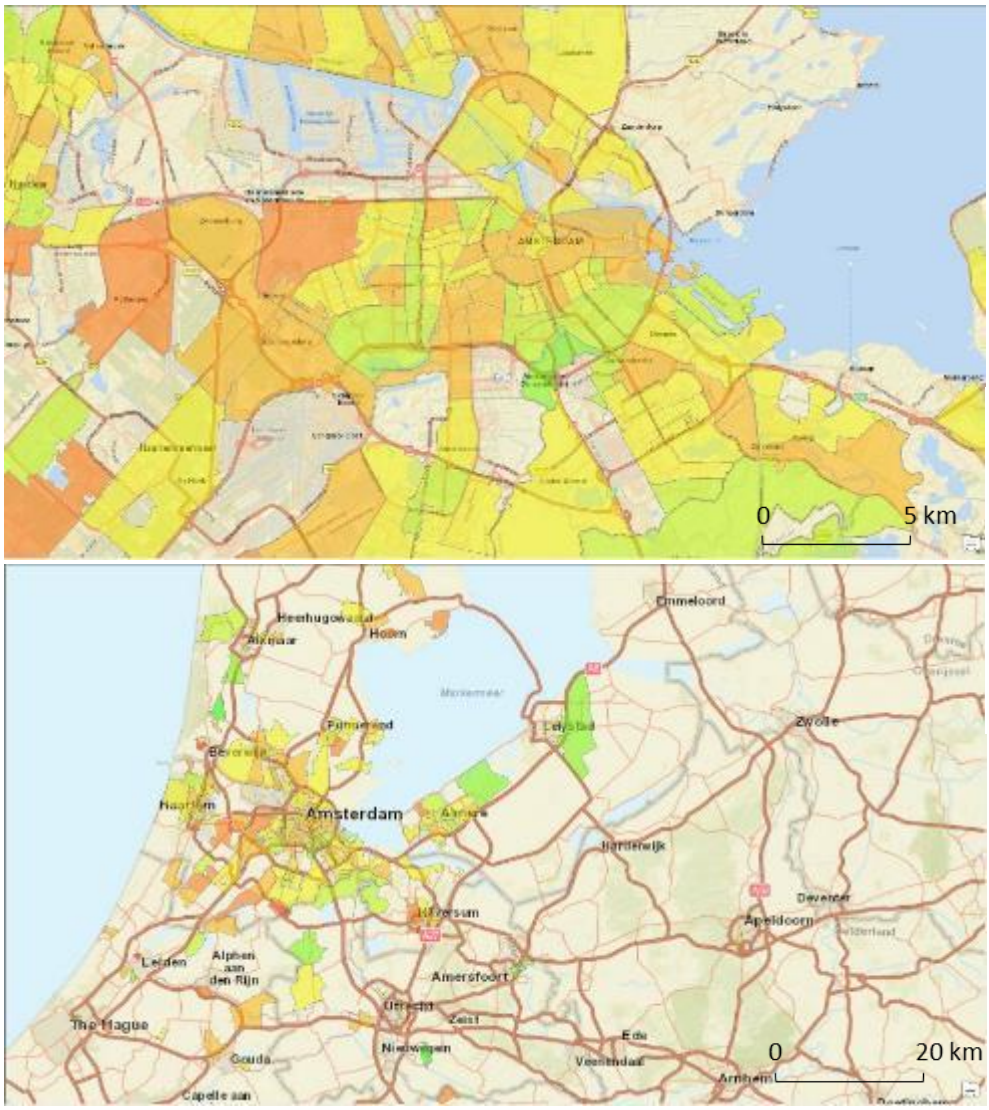
2010/2011



2016/2017

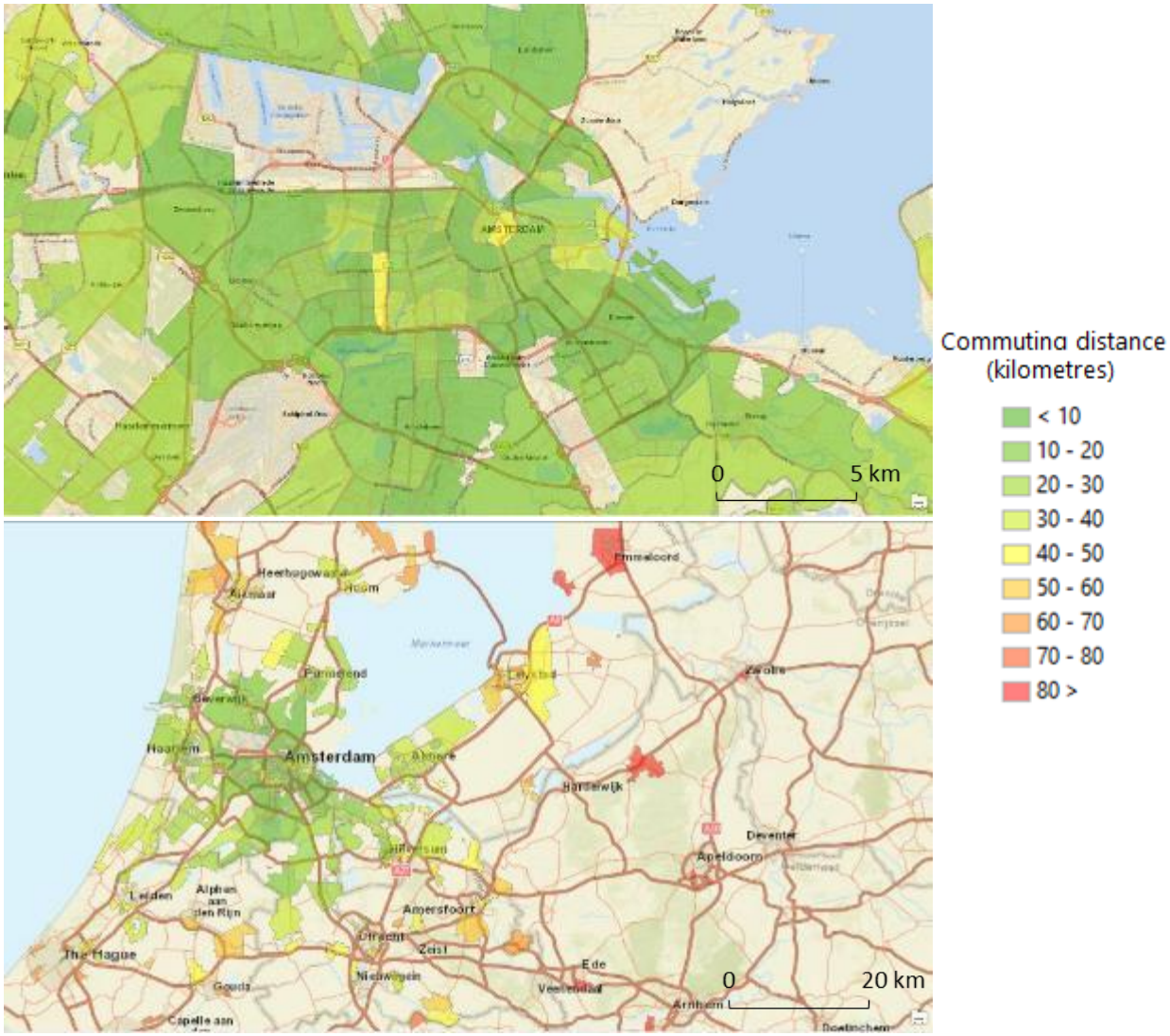

Mean income
Low income
High income
0
5 km
0
20 km
Amsterdam
The Hague
Utrecht
Zwolle
Emmeloord
Lelystad
Almere
Hoorn
Amersfoort
Apeldoorn
Deventer
Leiden
Alphen aan den Rijn
Gouda
Nieuwegein
Zeist
Arnhem
Ede
Haarlem
Hilversum

Change in mean income

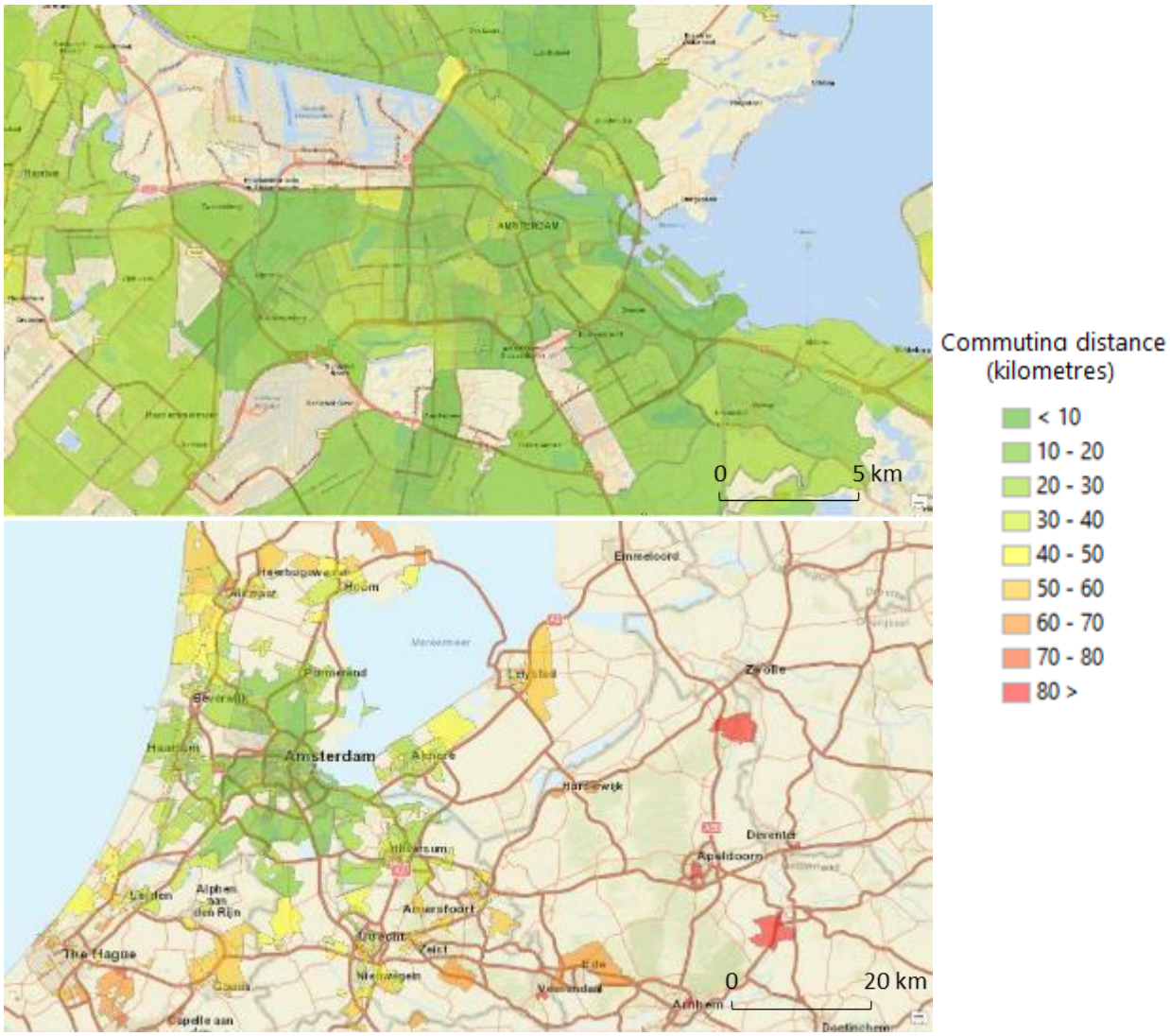


Mean commuting distance (in kilometres)

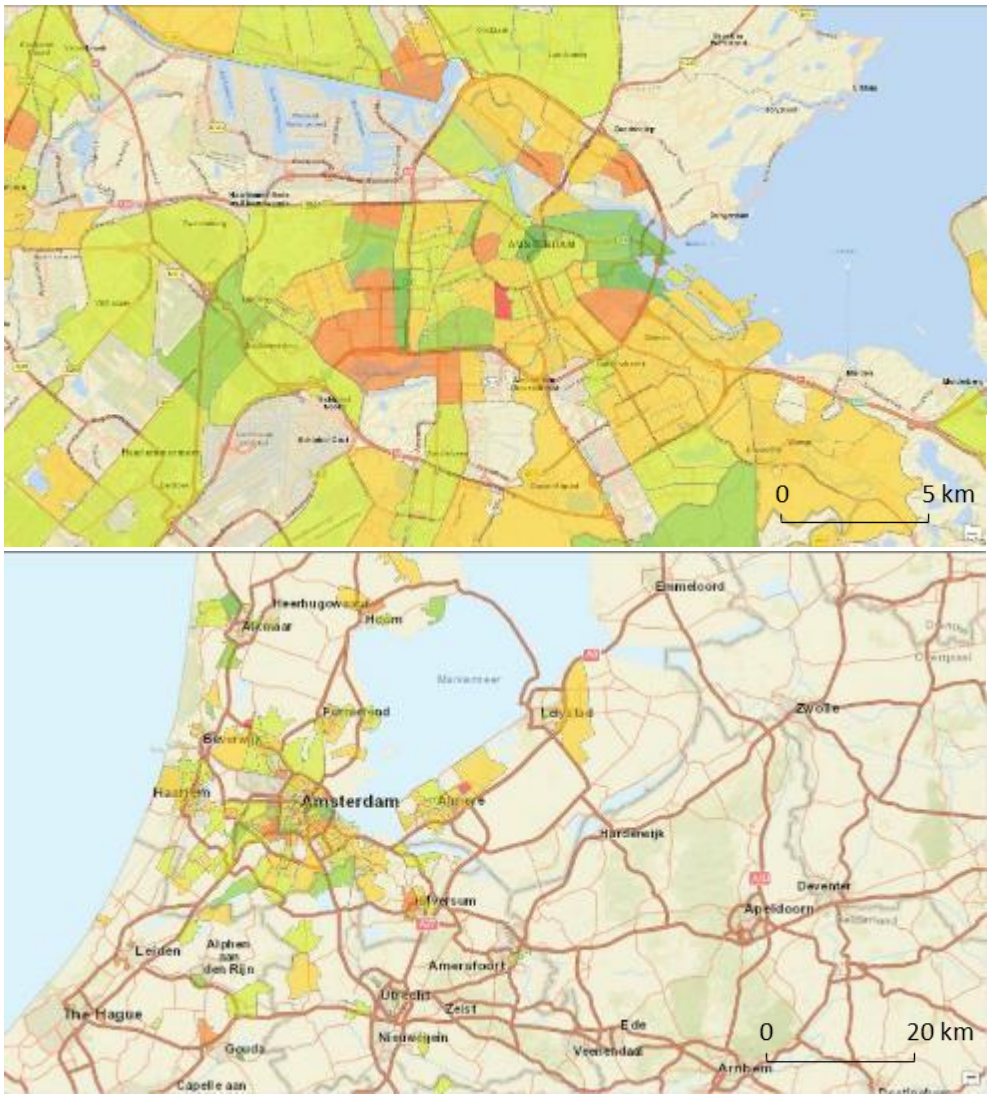
2010/2011



2016/2017

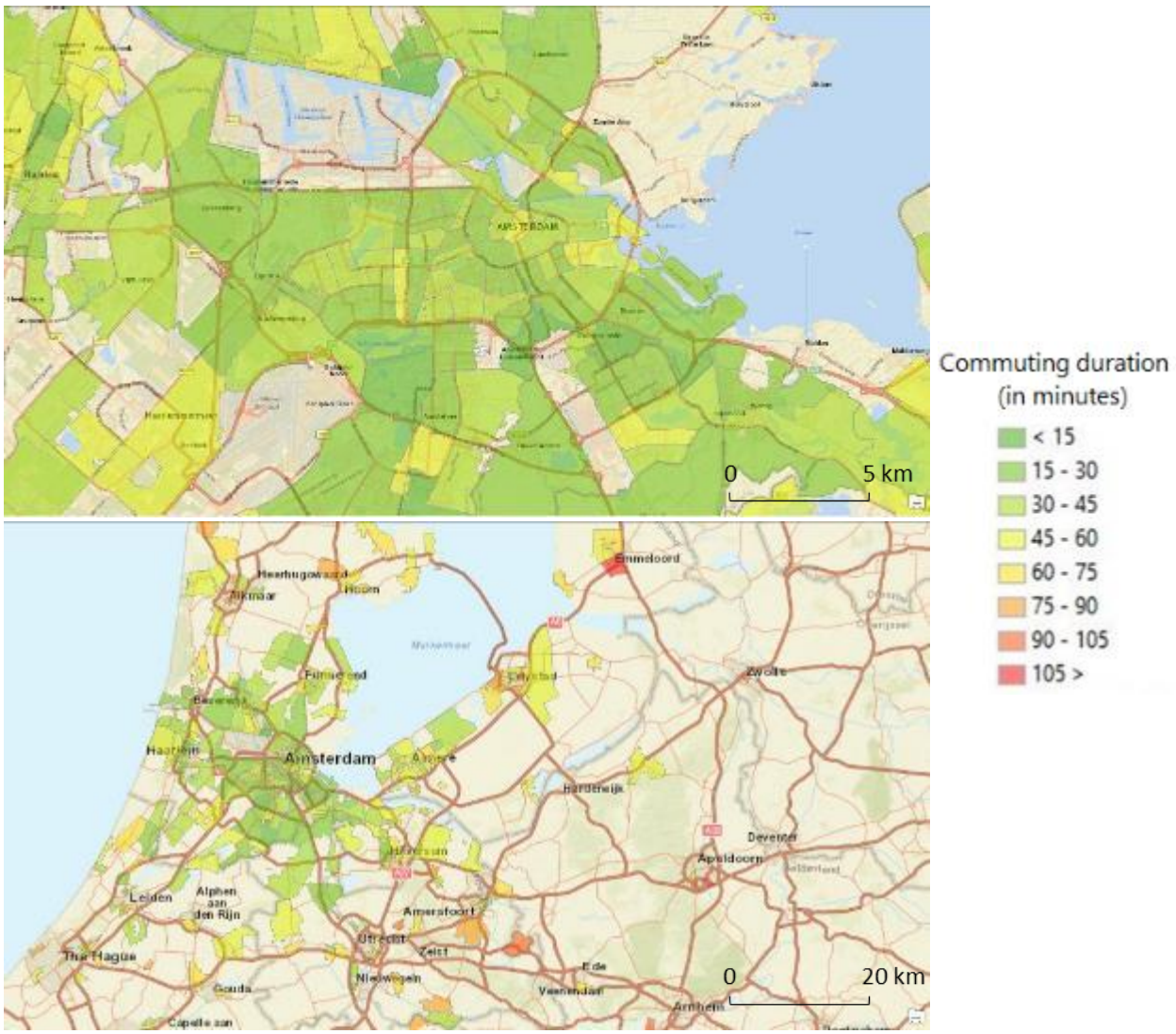

AMSTERDAM
0
5 km
Amsterdam
Zwolle
Apeldoorn
Amersfoort
The Hague
0
20 km
Commuting distance (kilometres)
< 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 >

Change in mean commuting distance



Mean commuting duration (in minutes)

2010/2011

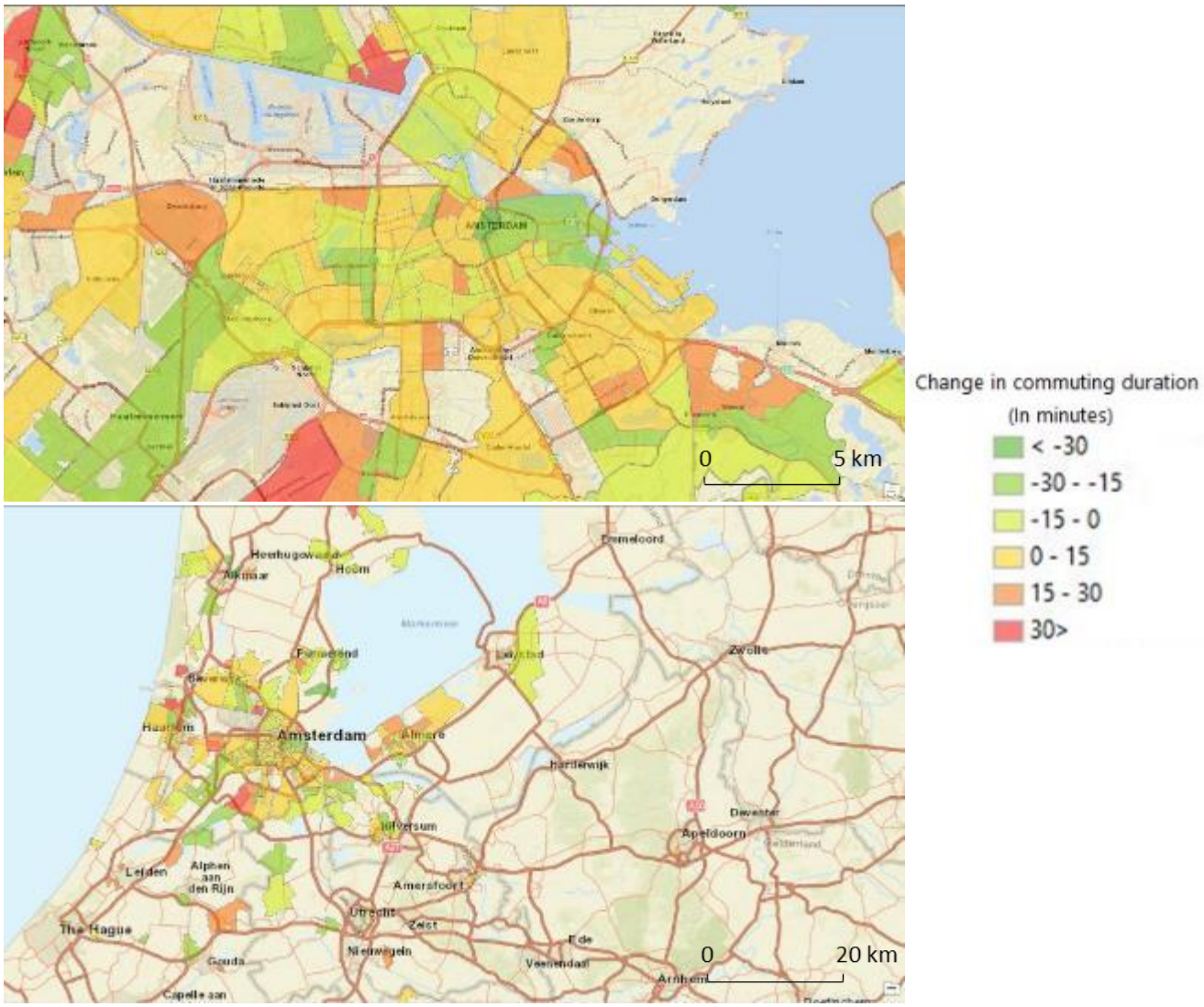


2016/2017

Commuting duration (in minutes)

- < 15
- 15 - 30
- 30 - 45
- 45 - 60
- 60 - 75
- 75 - 90
- 90 - 105
- 105 >

Change in mean commuting duration



Appendix IV: Data analysis tables

Respondent count (without weight factor)

Table IV.1

Respondent count in 2010/2011 .

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Total*
Workplace location	Central Amsterdam CS	2		2	13	1	25	43
	Central Amsterdam WTC		2	1	15	1	31	50
	Central elsewhere in Amsterdam	1	3	33	158	33	229	457
	Not central in Amsterdam	3	1	24	86	27	213	354
	Central elsewhere outside Amsterdam	2	1	3	41			47
	Not central outside Amsterdam	1	2	24	71			98
	Total	9	9	87	384	62	498	1,049

Table IV.2

Respondent count in 2016/2017 .

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Total*
Workplace location	Central Amsterdam CS		1	3	23	3	28	58
	Central Amsterdam WTC		3	3	14	5	45	70
	Central elsewhere in Amsterdam	10	9	60	233	35	281	628

	Not central in Amsterdam		1	39	113	32	179	364
	Central elsewhere outside Amsterdam	1	3	13	46			63
	Not central outside Amsterdam	4	3	35	100			142
	Total	15	20	153	529	75	533	1,325

Table IV.3

Change in respondent count.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Total*
Workplace location	Central Amsterdam CS			1	10	2	3	15
	Central Amsterdam WTC		1	2	-1	4	14	20
	Central elsewhere in Amsterdam	9	6	27	75	2	52	171
	Not central in Amsterdam	-3	0	15	27	5	-34	10
	Central elsewhere outside Amsterdam	-1	2	10	5			16
	Not central outside Amsterdam	3	1	11	29			44
	Total	6	11	66	145	13	35	276

Respondent count (with weight factor)

Table IV.4

Respondent count (weight factor applied) in 2010/2011 .

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Total*
Workplace location	Central Amsterdam CS	1,376	0	1,458	10,737	753	11,037	25,361
	Central Amsterdam WTC	0	1,557	533	8,632	162	12,693	23,577
	Central elsewhere in Amsterdam	403	1,903	21,930	103,525	17,046	88,241	233,048
	Not central in Amsterdam	1,722	589	16,643	55,093	11,933	75,130	161,109
	Central elsewhere outside Amsterdam	1,740	535	1,782	25,085			29,141
	Not central outside Amsterdam	438	1,077	14,909	44,906			61,330
	Total	5,679	5,661	57,255	247,977	29,894	187,100	533,566

Table IV.5

Respondent count (weight factor applied) in 2016/2017 .

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Total*
Workplace location	Central Amsterdam CS		698	1,435	10,812	1,629	12,091	26,666
	Central Amsterdam WTC		720	807	6,487	2,488	18,964	29,465
	Central elsewhere in Amsterdam	4,211	3,619	26,934	107,566	17,107	113,194	272,632
	Not central in Amsterdam		255	17,952	52,629	14,965	70,223	156,024
		98	1,127	6,173	20,471			27,869

	Central elsewhere outside Amsterdam							
	Not central outside Amsterdam	1,833	1,162	14,561	49,767			67,324
	Total	6,142	7,580	67,862	247,732	36,190	214,472	579,979

Table IV.6

Change in respondent count (weight factor applied).

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Total*
Workplace location	Central Amsterdam CS			-23	75	876	1,054	1,305
	Central Amsterdam WTC		-837	274	-2,145	2,326	6,271	5,888
	Central elsewhere in Amsterdam	3,808	1,716	5,003	4,041	61	24,953	39,583
	Not central in Amsterdam		-334	1,309	-2,464	3,033	-4,906	-5,085
	Central elsewhere outside Amsterdam	-1,642	592	4,391	-4,613			-1,273
	Not central outside Amsterdam	1,395	85	-347	4,862			5,994
	Total	463	1,919	10,607	-245	6,296	27,372	46,413

Mean household income

Table IV.7

Mean household income in 2010/2011.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS	2.00		2.50	1.88	1.00	2.29	2.07
	Central Amsterdam WTC		1.47	2.00	2.80	2.00	2.79	2.69
	Central elsewhere in Amsterdam	4.00	1.46	2.30	2.02	2.35	2.40	2.21
	Not central in Amsterdam	3.63	4.00	1.66	2.16	2.72	2.66	2.40
	Central elsewhere outside Amsterdam	3.10	5.00	3.21	2.32			2.47
	Not central outside Amsterdam	3.00	3.00	2.02	2.09			2.10
	Average	3.05	2.36	2.07	2.11	2.46	2.52	2.29

Table IV.8

Mean household income in 2016/2017.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS		2.00	1.35	2.24	1.36	2.65	2.32
	Central Amsterdam WTC		1.91	4.00	2.33	4.15	2.98	2.94
	Central elsewhere in Amsterdam	3.21	2.70	2.47	2.56	2.68	2.95	2.73
	Not central in Amsterdam		5.00	2.60	2.72	2.67	3.13	2.89
		4.00	3.03	2.56	3.01			2.91

	Central elsewhere outside Amsterdam							
	Not central outside Amsterdam	2.98	3.07	2.85	2.72			2.76
	Average	3.16	2.75	2.59	2.64	2.71	3.00	2.78

Table IV.9

Change in mean household income.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS			-1.16	0.35	0.36	0.36	0.24
	Central Amsterdam WTC		0.44	2.00	-0.47	2.15	0.19	0.26
	Central elsewhere in Amsterdam	-0.79	1.25	0.17	0.54	0.33	0.55	0.52
	Not central in Amsterdam		1.00	0.94	0.56	-0.06	0.47	0.48
	Central elsewhere outside Amsterdam	0.90	-1.97	-0.65	0.68			0.44
	Not central outside Amsterdam	-0.02	0.07	0.82	0.63			0.66
	Average	0.11	0.39	0.52	0.53	0.25	0.48	0.49

Mean commuting distance (in kilometres)

Table IV.10

Mean commuting distance in 2010/2011

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS	3.0		5.5	6.1	23.7	30.9	17.2
	Central Amsterdam WTC		2.0	5.0	7.1	53.5	25.3	20.3
	Central elsewhere in Amsterdam	19.4	7.6	5.1	7.3	37.0	31.1	18.3
	Not central in Amsterdam	4.9	9.0	4.8	7.4	38.7	33.2	21.4
	Central elsewhere outside Amsterdam	73.8	55.0	22.9	42.3			43.2
	Not central outside Amsterdam	36.6	33.9	26.6	31.8			30.6
	Average	29.0	30.0	11.2	15.2	37.4	31.5	21.7

Table IV.11

Mean commuting distance in in 2016/2017.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS		5.3	8.3	6.8	40.3	28.5	18.8
	Central Amsterdam WTC		1.6	4.0	5.2	48.6	28.6	23.8
	Central elsewhere in Amsterdam	6.5	6.2	6.0	7.1	38.7	37.5	21.5
	Not central in Amsterdam		10.0	7.2	7.5	43.1	37.2	24.3
		53.0	26.5	31.1	39.3			37.0

	Central elsewhere outside Amsterdam							
	Not central outside Amsterdam	40.2	31.1	28.0	36.8			34.9
	Average	17.3	12.6	13.4	15.7	41.2	36.1	24.6

Table IV.12

Change in mean commuting distance.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS			2.8	0.7	16.6	-2.3	1.6
	Central Amsterdam WTC		-0.4	-1.0	-1.9	-4.9	3.2	3.5
	Central elsewhere in Amsterdam	-12.9	-1.4	0.9	-0.2	1.7	6.4	3.3
	Not central in Amsterdam		1.0	2.5	0.1	4.4	4.1	2.8
	Central elsewhere outside Amsterdam	-20.8	-28.5	8.1	-3.0			-6.2
	Not central outside Amsterdam	3.6	-2.8	1.4	5.1			4.3
	Average	-11.7	-17.4	2.2	0.5	3.8	4.6	2.9

Mean commuting duration (in minutes)

Table IV.13

Mean commuting duration in 2010/2011.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS	24.3		17.5	19.3	32.0	45.4	31.2
	Central Amsterdam WTC		15.0	15.0	29.7	64.0	44.7	39.9
	Central elsewhere in Amsterdam	52.0	26.6	22.4	23.2	58.3	46.3	34.5
	Not central in Amsterdam	24.4	45.0	19.5	34.9	54.6	48.5	41.0
	Central elsewhere outside Amsterdam	91.5	30.0	34.2	50.9			51.9
	Not central outside Amsterdam	50.0	36.6	42.2	47.4			46.0
	Average	48.9	40.9	26.9	33.0	56.2	47.0	37.8

Table IV.14

Mean commuting duration in 2016/2017.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS		30.0	15.2	25.5	61.1	49.8	38.3
	Central Amsterdam WTC		15.6	22.0	25.2	60.1	43.2	39.4
	Central elsewhere in Amsterdam	29.2	19.7	22.6	25.1	59.0	49.8	37.2
	Not central in Amsterdam		20.0	24.3	26.7	54.2	52.5	40.6
		75.0	48.1	54.0	54.6			54.3

	Central elsewhere outside Amsterdam							
	Not central outside Amsterdam	52.6	45.6	42.9	45.2			44.9
	Average	36.9	28.5	30.1	31.9	57.2	50.1	39.9

Table IV.15

Change in mean commuting duration.

		Residential location						
		Central Amsterdam CS	*Central Amsterdam WTC*	*Central elsewhere in Amsterdam*	*Not central in Amsterdam*	*Central elsewhere outside Amsterdam*	*Not central outside Amsterdam*	*Average*
Workplace location	Central Amsterdam CS			-2.3	6.2	29.1	4.5	7.1
	Central Amsterdam WTC		0.6	7.0	-4.5	-3.9	-1.6	-0.6
	Central elsewhere in Amsterdam	-22.8	-6.9	0.2	2.0	0.8	3.5	2.7
	Not central in Amsterdam		-25.0	4.8	-8.2	-0.4	4.0	-0.4
	Central elsewhere outside Amsterdam	-16.5	18.1	19.8	3.8			2.4
	Not central outside Amsterdam	2.6	9.0	0.7	-2.2			-1.1
	Average	-12.0	-12.4	3.2	-1.1	1.0	3.1	2.1

Appendix V: Coding of each value per variable

Variable	Values
Commuting duration (in minutes)	-
Commuting distance (in kilometres)	-
Respondent resides in Amsterdam	0 = Outside Amsterdam 1 = Inside Amsterdam
Year of sample recording	2010/2011 = 2010 or 2011 2016/2017 = 2016 or 2017
Gender	0 = female 1 = male
Age (in years)	18, …, 67
Household composition	0 = One-person household 1 = Couple 999 = system missing
Household consists of child(ren)	0 = Household without child(ren) 1 = Household with children 999 = system missing
Highest completed education level	0 = lower educated (primary, mavo, vmbo) 1 = middle educated (havo, vwo, MBO) 3 = Higher educated (HBO, university) 999 = system missing
Standardised household income	0 = low income (below €20,000) 1 = middle income (€20,000-€50,000) 2 = high income (€50,000 or more) 999 = System missing
Main mode of transport	0 = Motorised vehicle 1 = Public transport 2 = Slow traffic
Residential location (measured from Amsterdam CS)	-
Residential location (measured from all IC stations)	-
Workplace location centrality (measured from all IC stations)	-
Weight factor	-

Appendix VI: Multicollinearity table

Table on next page

Table 5.1
Correlation diagram.

		Residential location distance	Workplace location distance	Income	Age	Gender	Employment	Highest completed education level	Main mode of transport	Household includes children	Household lives as couple
Residential location distance	Pearson Correlation	1	-,091**	-,052**	,062**	-,118**	,105**	,025**	-,037**	,107**	,148**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000	.000	.000
	N		1,092,629	1,092,629	1,092,629	1,092,629	1,092,629	1,071,581	1,092,629	1,056,338	1,056,338
Workplace location distance	Pearson Correlation	-,102**	1	,019**	-,037**	,024**	,037**	-,007**	-,174**	,026**	,045**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.000	.000	.000
	N	559,109		1,092,629	1,092,629	1,092,629	1,092,629	1,071,581	1,092,629	1,056,338	1,056,338
Income	Pearson Correlation	-,214**	,037**	1	-,139**	,026**	-,050**	,090**	,059**	,026**	-,053**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000	.000	.000
	N	559,109	559,109		1,092,629	1,092,629	1,092,629	1,071,581	1,092,629	1,056,338	1,056,338
Age	Pearson Correlation	,070**	-.001	-,159**	1	-,089**	-,038**	-,007**	-,065**	,041**	,064**
	Sig. (2-tailed)	.000	.505	.000		.000	.000	.000	.000	.000	.000
	N	559,109	559,109	559,109		1,092,629	1,092,629	1,071,581	1,092,629	1,056,338	1,056,338
Gender	Pearson Correlation	-,122**	,046**	,041**	-,084**	1	-,255**	-,079**	,130**	-,048**	-,109**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000	.000	.000
	N	559,109	559,109	559,109	559,109		1,092,629	1,071,581	1,092,629	1,056,338	1,056,338

Employment	Pearson Correlation	,108**	,033**	-,064**	,012**	-,230**	1	-,026**	-,065**	-,095**	,008**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.000	.000
	N	559,109	559,109	559,109	559,109	559,109		1,071,581	1,092,629	1,056,338	1,056,338
Highest completed education level	Pearson Correlation	,006**	-,022**	,083**	-,019**	-,099**	-,067**	1	-,064**	,097**	-,074**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000	.000	.000
	N	553,053	553,053	553,053	553,053	553,053	553,053		1,071,581	1,038,358	1,038,358
Main mode of transport	Pearson Correlation	-,027**	-,198**	,072**	-,108**	,107**	-,048**	-,067**	1	-,116**	-,075**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000		.000	.000
	N	559,109	559,109	559,109	559,109	559,109	559,109	553,053		1,056,338	1,056,338
Household includes children	Pearson Correlation	,109**	,018**	-,012**	,052**	-,041**	-,102**	,087**	-,139**	1	,365**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000		.000
	N	548,444	548,444	548,444	548,444	548,444	548,444	542,877	548,444		1,056,338
Household lives as couple	Pearson Correlation	,106**	,012**	-,072**	,013**	-,042**	-,041**	-,072**	-,034**	,370**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	N	548,444	548,444	548,444	548,444	548,444	548,444	542,877	548,444	548,444	

Note: Top top/right: 2016/2017, bottom/left: T=2.

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix VII: SPSS Syntaxes

Data cleaning

First cleaning round, selecting only commuting trips:

```
FILTER OFF.
USE ALL.
SELECT IF (MotiefV = 1).
EXECUTE.

DATASET COPY Naar_werk.
DATASET ACTIVATE Naar_werk.
FILTER OFF.
USE ALL.
SELECT IF (VerplNr = 1 & Vertrekp = 1 & Doel = 2).
EXECUTE.
DATASET ACTIVATE DataSet1.

DATASET COPY Naar_huis.
DATASET ACTIVATE Naar_huis.
FILTER OFF.
USE ALL.
SELECT IF (Doel = 1 & VerplNr >= 2).
EXECUTE.
DATASET ACTIVATE DataSet1.
```

Second cleaning, erasing duplicate trips (only one commuting trip per respondent) and erasing commuting trips without while recording not to be employed, and trips made by respondents that reside of work abroad or having travelled via Belgium or Germany during the commute:

```
SORT CASES BY OPID(A).
MATCH FILES
 /FILE=*
 /BY OPID
 /DROP = PrimaryFirst_OPID /FIRST=PrimaryFirst_OPID.
VARIABLE LABELS PrimaryFirst_OPID 'Indicator of each first matching case as Primary'.
VALUE LABELS PrimaryFirst_OPID 0 'Duplicate Case' 1 'Primary Case'.
VARIABLE LEVEL PrimaryFirst_OPID (ORDINAL).
FREQUENCIES VARIABLES=PrimaryFirst_OPID.
EXECUTE.

DATASET COPY Second_cleaning.
DATASET ACTIVATE Second_cleaning.
```

```
FILTER OFF.
USE ALL.
SELECT IF (PrimaryFirst_OPID = 1 & ReisduurBL = 0 & AfstVBL = 0 & Employment >= 1 &
Employment <= 3
 & ResiPC >= 0001 & ResiPC <= 9999 & WorkPC >= 0001 & WorkPC <= 9999).
EXECUTE.
DATASET ACTIVATE DataSet3.
```

Third cleaning, erasing commuting trips that are most likely to be faulty:

```
DATASET ACTIVATE Second_cleaning.
DATASET COPY Third_cleaning.
DATASET ACTIVATE Third_cleaning.
FILTER OFF.
USE ALL.
SELECT IF ((ResiPC >= 1011 & ResiPC <= 1109 OR WorkPC >= 1011 & WorkPC <= 1109) & Age
>= 18 & Age <= 67 & CDistance <= 1200 & CTime <= 120).
EXECUTE.
DATASET ACTIVATE Second_cleaning.
```

Recoding variables

SPSS syntax used to recode values and add new variables based on existing data:

```
RECODE Gender (1=0) (2=1) INTO Gender.
VARIABLE LABELS Gender 'Gender'.

RECODE HHInc (7=999) INTO HHInc.
VARIABLE LABELS HHInc 'Income'.

RECODE HHInc_2 (1 thru 5=0) (6=1) (7=999) INTO HHInc_2.
VARIABLE LABELS HHInc_2 'Income_2'.

RECODE Employment (0=999) (1=1) (2=1) (3=0) (4=999) (5=999) INTO Employment.
VARIABLE LABELS Employment 'Employment'.

RECODE HHComp (8=999) INTO HHComp.
VARIABLE LABELS HHComp 'composition'.

RECODE Education (0=999) (1=0) (2=1) (3=2) (4=3) (5=999) (6=999) (7=999) INTO Education.
VARIABLE LABELS Education 'Education'.

RECODE TMode (1 thru 5=1) (6 thru 10=0) (11=1) (12=0) (13 thru 16=2) (17=0) (18=1) (20=2)
(21=0) (22 Thru 23=2) (ELSE=999) INTO TMode.
VARIABLE LABELS TMode 'TMode'.

RECODE HHComp (1=1) (2=1) (5=1) (3=0) (4=0) (6=0) (7=0) (8=999) INTO HHC_Child.
```

```
VARIABLE LABELS HHC_Child 'Household has children'.
EXECUTE.

RECODE HHComp (1=1) (6=1) (7=1) (2 thru 5=0) (ELSE=999) INTO HHC.
VARIABLE LABELS HHC 'Household includes a couple'.

RECODE Amsterdam (1011 thru 1109=1) (ELSE=0) INTO Amsterdam.
VARIABLE LABELS Amsterdam 'ResiPC in Amsterdam'.

RECODE Year (2010=0) (2011=0) (2016=1) (2017=1) INTO Year_group.
VARIABLE LABELS Year_group 'Dataset year grouping'.
EXECUTE.
```

Descriptive tables

SPSS syntax to construct a custom table that shows the mean commuting durations and commuting distances per variable category, for the total sample:

```
CTABLES
 /VLABELS VARIABLES=CDistance Gender Age HHInc TMode Education HHComp Employment Year_group
  DISPLAY=LABEL
 /TABLE CDistance [MEAN] > (Gender + Age + HHInc + TMode + Education + HHComp + Employment) BY Year_group
 /CATEGORIES VARIABLES=Gender Age HHInc TMode Education HHComp Employment ORDER=A KEY=VALUE
  EMPTY=INCLUDE
 /CATEGORIES VARIABLES= Year_group ORDER=A KEY=VALUE EMPTY=EXCLUDE
 /CRITERIA CILEVEL=95.

* Custom Tables.
CTABLES
 /VLABELS VARIABLES=Departure_Centrality HHInc Arrival_Centrality Year DISPLAY=LABEL
 /TABLE Departure_Centrality [MEAN] > HHInc + Arrival_Centrality [MEAN] > HHInc BY Year_group
 /CATEGORIES VARIABLES=HHInc ORDER=A KEY=VALUE EMPTY=INCLUDE
 /CATEGORIES VARIABLES=Year ORDER=A KEY=VALUE EMPTY=EXCLUDE
 /CRITERIA CILEVEL=95.

* Chart Builder.
GGRAPH
 /GRAPHDATASET NAME="graphdataset" VARIABLES=Arrival_Centrality CDistance Year_group MISSING=LISTWISE
  REPORTMISSING=NO DATAFILTER= Year_group(VALUES=0 UNLABELED=INCLUDE)
 /GRAPHSPEC SOURCE=INLINE
 /FITLINE TOTAL=YES.
BEGIN GPL
```

```
 SOURCE: s=userSource(id("graphdataset"))
 DATA: Arrival_Centrality=col(source(s), name("Arrival_Centrality"))
 DATA: CDistance=col(source(s), name("CDistance"))
 GUIDE: axis(dim(1), label("Centrality of workplace location"))
 GUIDE: axis(dim(2), label("Commuting distance (kilometres)"))
 GUIDE: text.title(label("Simple Scatter with Fit Line of Commuting distance (kilometres) by ",
  "Centrality of workplace location"))
 GUIDE: text.footnote(label("Filtered by Year_group variable"))
 ELEMENT: point(position(Arrival_Centrality*CDistance))
END GPL.

* Chart Builder.
GGRAPH
 /GRAPHDATASET NAME="graphdataset" VARIABLES=Departure_Centrality CDistance
Year_group
MISSING=LISTWISE
  REPORTMISSING=NO DATAFILTER= Year_group(VALUES=ALL UNLABELED=INCLUDE)
 /GRAPHSPEC SOURCE=INLINE
 /FITLINE TOTAL=YES.
BEGIN GPL
 SOURCE: s=userSource(id("graphdataset"))
 DATA: Departure_Centrality=col(source(s), name("Departure_Centrality"))
 DATA: CDistance=col(source(s), name("CDistance"))
 GUIDE: axis(dim(1), label("Centrality of residential location"))
 GUIDE: axis(dim(2), label("Commuting distance (kilometres)"))
 GUIDE: text.title(label("Simple Scatter with Fit Line of Commuting distance (kilometres) by ",
  "Centrality of residential location"))
 GUIDE: text.footnote(label("Filtered by Year_group variable"))
 ELEMENT: point(position(Departure_Centrality*CDistance))
END GPL.

* Chart Builder.
GGRAPH
 /GRAPHDATASET NAME="graphdataset" VARIABLES=Departure_Centrality CDistance
Year_group
MISSING=LISTWISE
  REPORTMISSING=NO
 /GRAPHSPEC SOURCE=INLINE
 /FITLINE TOTAL=NO SUBGROUP=NO.
BEGIN GPL
 SOURCE: s=userSource(id("graphdataset"))
 DATA: Departure_Centrality=col(source(s), name("Departure_Centrality"))
 DATA: CDistance=col(source(s), name("CDistance"))
 DATA: Year_group=col(source(s), name("Year_group"), unit.category())
 GUIDE: axis(dim(1), label("Centrality of residential location"))
 GUIDE: axis(dim(2), label("Commuting distance (kilometres)"))
 GUIDE: legend(aesthetic(aesthetic.color.exterior), label("Year_group"))
```

```
 GUIDE: text.title(label("Grouped Scatter of Commuting distance (kilometres) by Centrality of ",
  "residential location by Year_group"))
 SCALE: cat(aesthetic(aesthetic.color.exterior), include("2010/2011", "2016/2017"))
 ELEMENT: point(position(Departure_Centrality*CDistance), color.exterior(Year_group))
END GPL.
```

SPSS syntax to construct a custom table that shows the mean commuting durations and commuting distances per variable category, splitting by residing inside or outside Amsterdam:

```
USE ALL.
COMPUTE filter_$=(ResiPC >= 1110).
VARIABLE LABELS filter_$ 'ResiPC >= 1110 (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.

* Custom Tables.
CTABLES
 /VLABELS VARIABLES=CDistance Gender Age HHInc TMode Education HHComp Employment
Year_group
  DISPLAY=LABEL
 /TABLE CDistance [MEAN] > (Gender + Age + HHInc + TMode + Education + HHComp +
Employment) BY Year_group
 /CATEGORIES VARIABLES=Gender Age HHInc TMode Education HHComp Employment
ORDER=A KEY=VALUE
  EMPTY=INCLUDE
 /CATEGORIES VARIABLES= Year_group ORDER=A KEY=VALUE EMPTY=EXCLUDE
 /CRITERIA CILEVEL=95.

* Custom Tables.
CTABLES
 /VLABELS VARIABLES=Departure_Centrality HHInc Arrival_Centrality Year DISPLAY=LABEL
 /TABLE Departure_Centrality [MEAN] > HHInc + Arrival_Centrality [MEAN] > HHInc BY
Year_group
 /CATEGORIES VARIABLES=HHInc ORDER=A KEY=VALUE EMPTY=INCLUDE
 /CATEGORIES VARIABLES=Year ORDER=A KEY=VALUE EMPTY=EXCLUDE
 /CRITERIA CILEVEL=95.

* Chart Builder.
GGRAPH
 /GRAPHDATASET NAME="graphdataset" VARIABLES=Arrival_Centrality CDistance Year_group
MISSING=LISTWISE
  REPORTMISSING=NO DATAFILTER= Year_group(VALUES=1 UNLABELED=INCLUDE)
 /GRAPHSPEC SOURCE=INLINE
 /FITLINE TOTAL=YES.
```

```
BEGIN GPL
 SOURCE: s=userSource(id("graphdataset"))
 DATA: Arrival_Centrality=col(source(s), name("Arrival_Centrality"))
 DATA: CDistance=col(source(s), name("CDistance"))
 GUIDE: axis(dim(1), label("Centrality of workplace location"))
 GUIDE: axis(dim(2), label("Commuting distance (kilometres)"))
 GUIDE: text.title(label("Simple Scatter with Fit Line of Commuting distance (kilometres) by ",
  "Centrality of workplace location"))
 GUIDE: text.footnote(label("Filtered by Year_group variable"))
 ELEMENT: point(position(Arrival_Centrality*CDistance))
END GPL.

* Chart Builder.
GGRAPH
 /GRAPHDATASET NAME="graphdataset" VARIABLES=Departure_Centrality CDistance
Year_group MISSING=LISTWISE
  REPORTMISSING=NO DATAFILTER= Year_group(VALUES=ALL UNLABELED=INCLUDE)
 /GRAPHSPEC SOURCE=INLINE
 /FITLINE TOTAL=YES.
BEGIN GPL
 SOURCE: s=userSource(id("graphdataset"))
 DATA: Departure_Centrality=col(source(s), name("Departure_Centrality"))
 DATA: CDistance=col(source(s), name("CDistance"))
 GUIDE: axis(dim(1), label("Centrality of residential location"))
 GUIDE: axis(dim(2), label("Commuting distance (kilometres)"))
 GUIDE: text.title(label("Simple Scatter with Fit Line of Commuting distance (kilometres) by ",
  "Centrality of residential location"))
 GUIDE: text.footnote(label("Filtered by Year_group variable"))
 ELEMENT: point(position(Departure_Centrality*CDistance))
END GPL.

* Chart Builder.
GGRAPH
 /GRAPHDATASET NAME="graphdataset" VARIABLES=Departure_Centrality CDistance
Year_group MISSING=LISTWISE
  REPORTMISSING=NO
 /GRAPHSPEC SOURCE=INLINE
 /FITLINE TOTAL=NO SUBGROUP=NO.
BEGIN GPL
 SOURCE: s=userSource(id("graphdataset"))
 DATA: Departure_Centrality=col(source(s), name("Departure_Centrality"))
 DATA: CDistance=col(source(s), name("CDistance"))
 DATA: Year_group=col(source(s), name("Year_group"), unit.category())
 GUIDE: axis(dim(1), label("Centrality of residential location"))
 GUIDE: axis(dim(2), label("Commuting distance (kilometres)"))
 GUIDE: legend(aesthetic(aesthetic.color.exterior), label("Year_group "))
 GUIDE: text.title(label("Grouped Scatter of Commuting distance (kilometres) by Centrality of ",
```

```
  "residential location by Year_group"))
 SCALE: cat(aesthetic(aesthetic.color.exterior), include("2010/2011", "2016/2017"))
 ELEMENT: point(position(Departure_Centrality*CDistance), color.exterior(Year_group))
END GPL.
```

Correlation tables

Syntax to construct a Pearson Correlations to check for multicollinearity in the 2010/2011 sample:

```
DATASET ACTIVATE DataSet1.
USE ALL.
COMPUTE filter_$=(Year_group = 0 & HHInc <= 6 & Education >= 2 & Education <= 4).
VARIABLE LABELS filter_$ 'Year_group = 0 & HHInc <= 6 & Education >= 2 & Education <= 4 (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.

CORRELATIONS
 /VARIABLES=Gender Age HHInc Employment HHComp Education TMode Departure_Centrality
  Arrival_Centrality
 /PRINT=ONETAIL NOSIG
 /MISSING=PAIRWISE.
```

Syntax to construct a Pearson Correlations to check for multicollinearity in the 2016/2017 sample:

```
DATASET ACTIVATE DataSet1.
USE ALL.
COMPUTE filter_$=( Year_group = 1 & HHInc <= 6 & Education >= 2 & Education <= 4).
VARIABLE LABELS filter_$ Year_group = 1 & HHInc <= 6 & Education >= 2 & Education <= 4 (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.

CORRELATIONS
 /VARIABLES=Gender Age HHInc Employment HHComp Education TMode Departure_Centrality
  Arrival_Centrality
 /PRINT=ONETAIL NOSIG
 /MISSING=PAIRWISE.
```

Regression equations

Regression equations syntaxes:
Selection criteria to ignore responses "unknown", and "other":

```
USE ALL.
COMPUTE filter_$=(HHInc <= 6 & Employment >= 1 & Employment <= 3 & HHComp <= 3 & Education <= 4 &
  TMode <= 4).
VARIABLE LABELS filter_$ 'HHInc <= 6 & Employment >= 1 & Employment <= 3 & HHComp <= 3 & '+
  'Education <= 4 & TMode <= 4 (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.
```

Regression syntax commuting distance 2010/2011:

```
 /SELECT=Year_group EQ 0
 /MISSING LISTWISE
 /STATISTICS COEFF OUTS CI(95) R ANOVA
 /CRITERIA=PIN(.05) POUT(.10)
 /NOORIGIN
 /DEPENDENT CDistance
 /METHOD=ENTER Gender Age HHInc Employment HHComp Education TMode Departure_Centrality Arrival_Centrality
 /RESIDUALS HISTOGRAM(ZRESID)
 /SAVE ADJPRED.
```

Regression syntax commuting duration 2010/2011:

```
REGRESSION
 /SELECT= Year_group EQ 0
 /MISSING LISTWISE
 /STATISTICS COEFF OUTS CI(95) R ANOVA
 /CRITERIA=PIN(.05) POUT(.10)
 /NOORIGIN
 /DEPENDENT CTime
 /METHOD=ENTER Gender Age HHInc Employment HHComp Education TMode Departure_Centrality Arrival_Centrality
 /RESIDUALS HISTOGRAM(ZRESID)
 /SAVE ADJPRED.
```

Regression syntax commuting distance 2016/2017:

```
REGRESSION
```

```
 /SELECT= Year_group EQ 1
 /MISSING LISTWISE
 /STATISTICS COEFF OUTS CI(95) R ANOVA
 /CRITERIA=PIN(.05) POUT(.10)
 /NOORIGIN
 /DEPENDENT CDistance
 /METHOD=ENTER Gender Age HHInc Employment HHComp Education TMode
Departure_Centrality Arrival_Centrality
 /RESIDUALS HISTOGRAM(ZRESID)
 /SAVE ADJPRED.
```

Regression syntax commuting duration 2016/2017:

```
REGRESSION
 /SELECT= Year_group EQ 1
 /MISSING LISTWISE
 /STATISTICS COEFF OUTS CI(95) R ANOVA
 /CRITERIA=PIN(.05) POUT(.10)
 /NOORIGIN
 /DEPENDENT CTime
 /METHOD=ENTER Gender Age HHInc Employment HHComp Education TMode
Departure_Centrality Arrival_Centrality
 /RESIDUALS HISTOGRAM(ZRESID)
 /SAVE ADJPRED.
```