HOW PUBLIC TRANSPORT STRENGTHENS THE CITY EFFECT ON CAR OWNERSHIP

Case of the Netherlands

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Chapter 1. Introduction

With the improvement of living standards, private cars are becoming more affordable for most people; however, the increasing level of car holdings and usages by households would cause serious problems such as traffic congestion, road accidents and air pollution (Bhat & Sen, 2006; Eakins, 2013). As noticed by 2001 National Household Transport Survey (NHTS), in the United States personal use of vehicles contributes to 87% daily trips. There is also research showing 42.5% of overall transport energy use in Ireland is due to private use of cars (Eakins, 2013). With this trend, policy makers are always trying to stimulate people to use cars less.

Many developed countries are facing demographic changes in recent decades (Batini et al., 2006) such as depopulation and aging population. Therefore, they estimate if the changing characteristics of households will influence car ownership.

Except for demographic researches, there are also a number of studies analyzing the determinants of household car ownership by focusing on build environment and public transport factors (Dargay, 2002; Whelan, 2007; Yagi & Managi, 2016). Research by Oakil et al. (2016) shows that car ownership is possibly higher in low density areas in the Netherlands, which might due to better accessibility to public transport in urban areas. While also a lot of studies drew on the influence of public transport in recent decades, but the results vary in different countries. Earlier research by Dargay and Vythoulkas (1999) found insignificant influence of public transport on car ownership in the UK, while research by Yagi and Managi (2016) shows that in Japan the development of public transport only has a considerably small effect on car ownership. But in general, most studies found negative influence of public transport on car ownership (Matas et al, 2008; Ritter & Vance, 2013; Eakins, 2013; Potoglou & Kanaroglou, 2008).

Seen from the previous studies, build environment, public transport, and household characteristics are all found to have some influences on car ownership. However, from a perspective of local authorities to control car ownership, build environment and household characteristics cannot be easily affected by policy makers, compared with public transport.

Therefore, in order to provide more valuable results and practical solutions, this paper is going to examine to which extent the level of car ownership depends on build environment (especially city effect), and how built environment (city effect) will be influenced by public transport. By controlling for household characteristics in a Linear Probability Model, this paper is going to analyze the effect by using a data of 166,937 respondents from OViN and CROW-KpVV in the Netherlands.

In the following chapters, the paper investigates and summarizes previous studies on car ownership in chapter 2, introduces the data and methodology in chapter 3, analyzes the results in chapter 4, and draws conclusions in chapter 5.

Chapter2. Literature Review

With rapidly increasing sales of private owned cars all over the world, people's travels are made more convenient by cars; however, many negative consequences are also rising; for example, traffic congestion, road accidents, and environmental costs (Eakins, 2013). Therefore, the determinants of car ownership have been highly focused and broadly researched in many countries.

Many papers investigated car ownership from a demographic point of view, searching for a relationship between household characteristics and car ownership. This is valuable for many countries where the population structure is rapidly changing. In this way examining the determinants of car ownership can help relevant industries and government to make accurate prediction of the future business demand (Yagi & Manafi, 2016).

Car ownership has also been investigated a lot in public transport field. And a negative relationship between public transport and car ownership was found in most studies. This is also of great value for policy makers because government could simply develop better public transport in order to control car ownership.

There also exist a few spatial literature (Dargay, 2002) and travel researches (Ewing and Cervero, 2010) studying the influence of living locations or built environment on car ownership. These factors appear to have a very dominant influence on car ownership in many studies. This is valuable from a perspective of city building and developing because a more diversified living activities in urban areas will more likely to decrease the demand of cars in a household. However, most built environment factors are difficult to intervene or need a comparably larger effort to change. For factors like population density, the government could hardly control because people's behaviors are always difficult to predict. For factor like street design, mostly it needs a much larger effort to change from both the time and financial perspectives.

In this way, although built environment is found to be important for car ownership, this paper is also going to focus on public transport, which is much easier for policy makers to intervene. Therefore, this paper is going to study the city effect on car ownership and how public transport will influence the effect of city on car ownership: whether the city effect will be stronger with a good public transport system or not.

The following sections will introduce the mainly focused determinants of car ownership in previous studies. 2.1 and 2.2 will be the main focused factors in this paper, and some of the factors from 2.3 to 2.5 will be picked up as controlled variables. Finally, 2.6 will draw a table including all the interesting variables from previous studies.

2.1 Built environment

Built environment, being defined as the human-made space in which people live, work, and recreate on a day-to-day basis (Roof and Oleru, 2008), encompasses places and spaces created or modified by people including buildings, parks, and transport system (Srinivasan et al., 2003). As a broad concept, built environment was firstly divided into 3 different groups: density, diversity, and design (Cervero and Kochelman, 1997); and this furtherly developed into "5 Ds" which also includes destination accessibility, and distance to transit (Ewing and Cervero, 2010).

2.1.1 Density

Density is always measured as a variable of interest per unit of area (Ewing and Cervero, 2010; Zhang et al., 2014). The commonly used variables of interest could be population density, dwelling unit density, and employment density within a gross or net area. While for car ownership researches, residential density is the most popular used attribute among researchers. They found out that a different pattern was often followed by car ownership due to residential characteristics. A few studies argue residential density indicates basic infrastructure within a city such as public transport accessibility (Matas & Raymond, 2008; Oakil et al., 2016) and spatial distribution of activities (Matas & Raymond, 2008). So it is found to be a very important factor for car ownership studies.

Estimating residential density by classifying cities into different sizes in Spain, Matas and Raymond (2008) drew a conclusion that when controlling for a fixed household income, the negative relationship between city size and car ownership tends to be more obvious in 2000s compared to 1980s, which indicates people are more dependent on cars in small cities where people see cars more as a necessary good. Similarly, Caulfield (2012) analyzed a census of 1.8 million individuals in Ireland and pointed out that people living in an area with lower density are more likely to own one or multiple cars.

Yagi & Manafi (2016) also found evidence in Japan that car ownership is more likely to increase in areas with higher density. However, when studying the effects of population and population density together, with prefectural area being constant, the authors also concluded that for most of the car types, a decrease in population is more likely to cause an increase in car ownership, which is due to a higher degree of living area per capita so forth a higher car demand (car ages 2-12).

Oakil et al. (2016) reached similar results by classifying it into 5 groups according to the number of addresses per km2 in the Netherlands. More specifically, Oakil et al. (2016) think different household characteristics might limit the wish or ability for a household to own a car, so they investigated the interaction effects between urbanization level with household composition and found in their dataset that the possibilities for different households to own a car differ in a same location. Therefore, the authors conclude the influence of residential density among young families varies with different household compositions.

2.1.2 Diversity

Diversity, focusing on the amount of different uses of land in a given area and the degree to which they are presented (Ewing and Cervero, 2010; Zhang et al., 2014). Entropy measures of diversity is commonly used in build environment studies, where the value increases with more diversified uses of land. Since urban areas are always seen as center of business, culture, and activities; therefore, in car ownership studies, most papers included an urban dummy variable to distinguish urban and rural areas or to represent the urbanization level.

The main idea is that if the activities within an area are more diversified, it would decrease the attractiveness of going elsewhere for activities and decrease the need to travel long distances so that it makes holding a car less attractive (Benavente and Tudela, n.d.). Ritter and Vance (2013) estimated this factor by including an urban dummy variable and found a negative influence on car ownership in a household in Germany, which implies households' decisions shifts according to the land use policies. The findings also corroborate with the results in research by Eakins (2013), Moeckel and Yang (2016) that households living in rural areas will more likely to own (more) cars due to activities need; nonetheless, the smaller the urban area, the higher possibility the households will own a car. The results are also supported by studies in UK, with data from Family Expenditure Surveys in UK from 1982 to 1995, Dargay (2002) especially investigated the determinants of car ownership in households living in different areas and he found sensitivity to costs of owning cars increase with higher urbanization level.

2.1.3 Design

Design is always used to represent the characteristics of street network within an area. In big cities, the street networks are normally denser and highly interconnected compared with curving streets in suburban areas (Ewing and Cervero, 2010). Therefore, the street network would vary from auto-oriented environments from the pedestrian-oriented environments. In specific, the variables estimated for design mostly include the number/proportion of intersections/pedestrian crossings per unit area, average street width or block size (Ewing and Cervero, 2010; Zhang et al., 2014).

By studying the survey data from Chile national transport planning authorities of a randomly drawn sample with 15000 households, Zegras (2010) focused on street networks influence on car use in city Santiago and found that car uses apparently increases in a suburban street network environment. Other micro-level factors were also used to measure the effect but the results were shown to be not significant. By focusing on street block density in San Francisco Bay area, Bhat and Guo (2007) also reached similar results. Interestingly, Zhang et al. (2014) studies street network density in Zhongshan metropolitan area in China, and found street network density is the most important determinant of car use among all the built environment measures. The authors found households with more connection to more developed street networks will generate more car trips, which imply for the influence of highly densified street network on a higher car demand.

Except for the above aspects, parking supply was also studied by a few researches in Europe. Different from the US grid-like street patterns, most European cities are characterized by narrow streets due to well protected historical centers, where is more likely to cause a scarcity of parking places. (Maat et al., 2007; Pucher and Buehler, 2008; Benavente and Tudela, n.d.; Moeckel and Yang, 2016). This is also supported by research of Cho and Baek (2007) which specified the average parking capacity are influential on car ownership and travel behavior in Seoul.

2.1.4 Destination accessibility

Destination accessibility is always used to measure the ease of access to trip attractions (Ewing and Cervero, 2010). The most popular attributes measured include distance to the central business area, distance from home to workplace/closest store, and number of jobs reachable within a certain time (Ewing and Cervero, 2010).

By investigating 737 households in the Netherlands, Maat et al. (2007) studied work locations and found distance to work is closely associated with car ownership. This is also supported by Cho and Baek (2007), who found regional accessibility in Seoul has negative influence on car ownership and travel behavior. Tudela and Merino (2007) also supported the results from studying Chilean cities that the influence of the household location and its distance to relative activities is important. The authors also found longer distance to activities will cause higher car ownership. By analyzing the interview of 25618 households from Zhongshan Household Travel Survey, Zhang et al. (2014) especially studied the destination accessibility by measuring the number of jobs accessible within ten minutes' travel time and found it has significant negative effect on car ownership in Zhongshan city area in China. Also interestingly, in San Francisco, the effect of regional accessibility was found out to be not so important; instead, the negative effect of recreational accessibility is found to be more significant on car ownership (Bhat and Guo, 2007).

Overall, although most results show destination accessibility are important (Badoe and Miller, 2000; Ewing and Cervero, 2001), there is also paper pointed out that this is not something easy to be changed by feasible policies or planning (Brownstone, 2008).

2.1.5 Distance to transit

Distance to transit is always used to measure the level of transit service within a residential or working area (Zhang et al., 2014). Commonly used variables are for example distance between transit stops, number of stations per area, transit service coverage rate, distance from home/workplace to the nearest station (Zhang et al., 2014; 5Ds).

Transit in car ownership studies mostly refers to public transport; therefore, many studies separate public transport into a main researched focus, and differ public transport between availability and quality. In this paper, public transport is also going to be studied as a single section. According to the previous results, although built environment is found to be important in determining car ownership and usage, it is still something difficult for government or policy makers to intervene in terms of time and investment efforts. However, public transport is something can be easily changed. So in this paper we are going to focus on both built environment and public transport, and the interaction effects between these two aspects.

2.1.6 A summary of the built environment studies

Among all the 5 Ds aspects, density, diversity, and distance to transit are more well researched from all kinds of perspectives than design and destination accessibility. Although built environment is highly focused aspect and found to be important in car ownership studies, there are seldom studies include the interaction effect between built environment and public transport. It is also proposed by Zegras (2010) that a combination effect should be detected for car ownership analysis, to avoid biased forecasts.

2.2 Public transport

2.2.1 Public transport availability/usage

Public transport availability is a highly focused factor among the researches of car ownership. Many papers take this into account because they regard public transport as a substitute of owning private cars at home. Some researchers argue that a household living

in an area with easy access to public transport will have less need of cars, which might cause lower possibilities to own one or more cars.
Some researchers investigate the accessibility of public transport by estimate the numbers of public transport stations within an area, while some others find estimating distance or walking duration from a household to a nearest public transport station is more relevant. Caulfield (2012) has found evidence in Ireland by estimating the numbers of rail stations and bus stations within a household area, and the results show that a household living in an area with no or fewer rail/bus stations are more likely to own multiple cars. Ritter & Vance (2013) estimates the public transport accessibility from a perspective of walking duration from a household to the nearest transit stop, and found the influence on car ownership to be positive as well. By obtained OD survey information from the Inland Revenue Office and the regional office of the Transport Ministry in Chile, Benavente and Tudela (n.d.) found both a lower distance to nearest bus route and higher accessibility of shared taxis would associated with a lower car ownership.

There are also some papers arguing the usage of public transport is more valuable in research. Yagi and Manafi (2016) investigate public transport from a perspective of the usage frequency of train and bus in Japan, finding a negative effect of train or bus use on ordinary car ownership (car aged 2-12), while the effects are comparably small. On the contrary, this negative effect of public transport usage was found to be strong predictor of less/non car ownership in Ireland (Eakins, 2013).

2.2.2 Public transport quality

Public transport quality or services can be more easily influenced by policies. Some researchers are very interested in this factor because they want to see whether this is an effective way to intervene for a lower car ownership.

By focusing the metro network in the Greater Copenhagen Area with a 20% sample of the population there, Mulalic et al. (2016) argue the average distance from each address to the nearest metro station representing the quality of the public transport in an area, and found a shorter distance contributes a lot on a lower car ownership. More interestingly, the accessibility of job by public transport is also found to have same effects on car ownership in this paper. Different from the above research, in Spain, Matas & Raymond (2008) estimated public transport quality by calculating vehicle-kilometers run per inhabitant, and they found this factor in general is showing an increasingly weaker effect on average car ownership. However, this effect is found to be greater when a household decides to buy a second or a third car and when the household is locating in largest cities. Similarly, Ritter & Vance (2013) also found negative effects on car ownership by estimating the frequency of the public transport services in Germany.

Except for the researches in European countries, Cullinane (2002) carried on a face-to-face survey of 389 students from 5 universities in Hong Kong, and found an overall good and cheap public transport quality could deter people from owning a car by themselves; however, the study is limited and biased since the respondents chosen are young students who frequently using public transport. Moreover, considering the narrow street network design and high population density in the previous section, Hong Kong will not be an ideal city for car trips.

2.2.3 Public transport fees

By regarding public transport as a substitute for cars, there is also paper measured the costs of using public transport. Ritter and Vance (2013) estimated both the costs of car ownership and the costs of public transit use in Germany, and found if cost of owning a car is higher, or if the cost of public transit use is lower, car ownership will be significantly decreased.

2.3 Demographic factors

2.3.1 Household income

Household income is a very important factor of car ownership. Although high income households account for only a smaller fraction compared to low income ones in the sample from Chile, it is still found that households with higher income would afford owning a car more easily (Tudela & Merino, 2007). The results by Ritter & Vance (2013) in Germany also support the results that with increasing household income, people are more likely to buy a car. This is also similar in Spain, where Matas & Raymond (2008) found household income is significantly important in estimating car ownership both over time and over different sizes of cities. This is also similar in Japan by measuring a prefectural income per capita, that higher income would lead to higher car ownership (car aged under 12) Yagi & Manafi (2016).

Oakil et al. (2016) and Dargay (2002) also found evidence of the positive influence of income on car ownership in the Netherlands and UK, but the Dargay (2002) indicated the household income is more or less reflected in life cycle effect - age of household head. He argued that with the increasing age of a household head, the income level is also increasing, therefore, the household have easier access to cars. Also interestingly, Tudela & Merino (2007) distinguished between high income sectors and low income sectors, and they found higher income sectors has more obvious effect on car ownership.

Besides, there are also researchers argue household income could be more easily be reflected in occupation, Caulfield (2012) studied the case of Dublin and contributed a positive effect of household income on car ownership by using occupation as a proxy.

2.3.2 Household composition

Household composition is considered as an important factor on car ownership as well. One reason is demography keeps changing rapidly in recent decades: household size is becoming smaller and smaller and population in many countries is increasingly aging. This will affect household characteristics from the perspective of household composition. Therefore, it attracts the attention of researchers from many countries since many researchers think this will influence the demand of transport and further the car ownership.

Some researchers investigate household composition from the perspective of the size of a household. Ritter & Vance (2013) analyzed a 10 years' German Mobility Data of 5052 households in Germany, and found bigger household size and older age composition will increase the possibility to own a car within a household. Interestingly, some other papers argue that suppose population being constant, an average larger household size means more efficient use of cars, therefore a smaller car ownership in general. This is supported by Yagi & Manafi (2016) by studying the case in Japan that when the average household size decreases by 0.1 person, the car ownership (numbers) will increase by 2% or 3%.

More specifically, some other papers also found the possibility of owning a car or more cars will highly increase if there are more adults within a household. This is supported by Matas & Raymond (2008) who found a household in Spain with more adults are more likely to own more cars, and they also found this effect to be more obvious among employed adults.

Except for the number of adults, the existence of children within a household is also investigated as a specific household composition (Oakil et al., 2016; Dargay, 2002). However, it was found by Dargay (2002) that the effect of number of adults is more significant in comparison with the number of children in a household in UK. Oakil et al (2016) distinguished households into different groups more specifically into different groups for 861,000 Dutch young households aging from 18 to 29 years old, and finally found young couples and young two-parent families have higher possibilities to own a car due to a more complex family activities pattern. Caulfield (2012) also contributed the findings by analyzing the case of Ireland that couples and couples with children tend to have more than one car available in a household. Also, Mulalic et al. (2016) and Eakins (2013) provided similar evidence from the context of Denmark and Ireland that more employed persons or more children within a household will probably cause a higher possibility to own a car.

2.4 Individual characteristics

People differ from each other in age, occupation, and gender, all of which might also lead to different decisions of owning a car in households. Therefore, individual characteristics are also important to be considered to estimate the effect on car ownership.

2.4.1 Age

As for age, many papers were investigating the age of a household head. In Spain, Matas & Raymond (2008) found that a household with a head between 25 to 65 years old will have a higher possibility to own more than one car. Eakins (2013) also concludes that if head of a household is older, it is more likely they will have more than one car. In UK, Dargay (2002) contributes the findings with similar results that under age 50, if the head of a household is older, the possibility of this household to own a car is higher.

Moreover, age was also broadly investigated to show the life-cycle effect/generation effect. Many researchers think people born in different time might have different preferences or accesses to hold a car or more cars, so it means people with different ages tend to make different decisions of owning one or multiple cars. Matas & Raymond (2008) and Dargay (2002) contributed to the generation effect that car ownership tends to be higher for more recent generation when controlling the age of household head being the same. Similarly, Caulfield (2012) finds in Ireland younger people are more likely coming from households with multiple cars. However, the generation effect was found to be weaker in most recent generations (Matas & Raymond, 2008; Dargay, 2002). But Dargay (2002) mentioned this effect not persuasive enough in UK case study due to a large standard error.

Last but not least, some other papers estimated the general age level of a society. The idea is that an aging society will possibly lead to less car ownership because of more need for nurse use instead of work use, but on the other hand it might also lead to more car ownership because of a higher ratio of driving license procession. By analyzing different types of cars and the differences between using or holding cars, Yagi & Manafi (2016) pointed out the results to be complicated in Japan.

2.4.2 Occupation

As for employment, many people see this as a need of owning car because employed people might have greater needs of mobility and larger economic activity scope (Leibling, 2008; Tudela & Merino, 2007). Furtherly, among the employed people, most papers also found high skilled workers tend to have higher possibility to own a car or more cars themselves. Oakil et al. (2016) pointed out that in the Netherlands employed young adults would have higher possibility to own a car. Tudela and Merino (2007) also found similar results in Chile that the likelihood of owning a car tends to be higher if the respondent is an independent worker. More specifically, this is also supported by Caulfield (2012) from the study in Ireland that people working as professionals or managers who are considered as higher income group would more likely to own one or more cars; however, the occupation here is actually used as a proxy to estimate household income.

2.4.3 Gender

As for gender, males are considered to have higher desire to own a car than female. This is supported by Matas and Raymond (2008), who found a household with male head is more likely to own at least one car when controlling for public transport quality, total yearly expenditure, age of head and number of non-working adults. However, this was found less important in smaller cities in Spain. Tudela & Merino (2007) also found evidence in Chile that a male head in a household will increase the possibility of owning a car at home. The authors also investigated the interaction effect of gender and driving license, and found female driver with a driving license would positively affect the possibility of car possession in a household.

2.5 Others

2.5.1 Costs of purchasing and owning a car

Seeing cars as a kind of goods, people's decision to buying/owning a car is also highly influenced by the costs of purchasing or owning a car, such as purchase prices, running prices (taxes, maintenance, petrol fees), and the fares of alternative transport modes (Caulfield, 2012; Dargay, 2002). Therefore, it is understandable if cars are staying at higher prices it would be less likely for people to buy a car.

Matas and Raymond (2008) estimated and included the price index effect in the constant term; and interestingly, the authors found a negative relationship with a weak significance in large cities, while a positive and highly significant influence in small and medium size cities. The authors explained the positive effect as a reduction in the real hedonic prices of cars. Dargay (2002) also investigated this effect in UK and found compared to fuel costs, people are more sensitive to purchasing costs considering car ownership, and the price elasticity tends to be twice higher in urban area than in rural area, which can to some extent imply people are less relied on cars in urban areas which might due to better transport possibilities. Differently, Yagi & Manafi (2016) controlled the fuel price and found no effect for some types of cars aged 2-11 but a stronger negative effect for cars aged 12+.

2.6 Table of variables studied in previous researches

Table 1. Variables studied in previous researches

Variables	**Description**	**Expected sign (+, -)**
Residential density	The residential density of an area	-

Urban/rural areas (urban dummy)	Dummy variable to distinguish urban and rural areas	-
Diversity	More different uses of land	-
Design (urban design)	Characteristics of street network design	-
Destination accessibility	Ease of access to trip attractions	-
Distance to public transport	The distance of a household to the nearest public transport. (bus, metro, train, tram, etc)	+
Public transport density	The amount of public transport within a specific area.	-
Public transport quality	Public transport quality	-
Public transport fares	The average fare of a specific public transport.	-
Household income	The average income of a household.w	+
Household size	The number of people within a household.	+
Household composition	The composition of a household (e.g. couples, single, with kids, etc)	+
Household employment status	Nr of employed workers within a household	+
Nr. of driving licenses	Indicates how many driving licenses a household has	+
Age	Age of household head	+
Gender (male)	The gender of household head	+
Occupation (high skilled)	Occupation of household head	+
Costs	Costs of car purchasing or maintenance	-

Chapter 3. Data and Methodology

3.1 Data

This study combines variables from two datasets: Onderzoek Verplaatsingen in Nederland (OViN) and Centrum voor Regelgeving en Onderzoek in de Grond-, Water- en Wegenbouw en de Verkeerstechniek (CROW).

Carried out by Centraal Bureau voor de Statistiek (CBS, 2015) from 1980s, OViN provides adequate information on the daily mobility of the Dutch population. The information is used a lot in the development and testing of the traffic and transport policy in the Netherlands. The selected period of time from OViN is from 2010 to 2014, of which the basic research here is a continuous daily investigate of the travel behaviour of Dutch people. Respondents are asked to record every trip information (where they go, for what purpose, how long it takes) on a certain day of the year. Some personal and household characteristics were also asked like vehicle ownership, education, household income and composition. In OViN, variables including car ownership, urbanity, education, household income and household composition will be used.

The survey by OViN was conducted very carefully in all researching stages, from sampling, processing, to weighting and analyzing. To keep the sample information broad and objective enough, every year a new sample framework is used, targeting at all individuals living in a household in the Netherlands who are registered in Gemeentelijke Basisadministratie (GBA). The questionnaire approaching strategies are mainly from three levels: firstly on internet, if no response then by phone, and finally a face-to-face interview if no response from the previous methods. In order to gain more accurate information, the data collection is also well designed with observation period being every day from January to December in the year. To make sure the samples selected is representative enough, the towns were drawn with opportunity proportional to the number of inhabitants, and in each province there is an equal opportunity for each individual to enter the sample. OViN is careful in correcting and weighting processes as well. A respondent's response containing 75% answers of "do not know" or "refuse to answer" will be seen as useless. Apocryphal answers like an enormous amount of car ownership will be seen as unserious response so that will be removed during inspection.

CROW is a non-profitable organisation providing knowledge and practical solutions for local authorities, contractors and consultants for both government cooperation and business work. The information in CROW are in many areas: public space, work safety, traffic and transport, which always used for design, construction, and management of roads and other traffic and transport facilities. Instead of collecting data themselves, CROW is specialized in estimation and calculation of data by using GIS model. Selected from the Klimmat Dashboard "Trends en ontwikkelingen op het gebied van duurzame en slimme mobiliteit" on CROW-KpVV (Kennis Platform Verkeer en Vervoer, 2017), this paper will use the ratios of people who do not have public transport nearby in each city for analysis.

3.2 Variables description

3.2.1 Dependent variable

3.2.1.1 Car ownership – Car_Yes & Car_more

In general, the dataset shows the total percentage of households which own cars slightly decreased by 1 percent from 2010 to 2013, with a total 166,937 observations. On average, in the Netherlands a household have 1.3 cars available. Most of the households are found to own 1 car, which accounts for over 50% of the sample, followed by 30% households which are owning 2 cars and 11% households owning no car. *(See figure 1)*

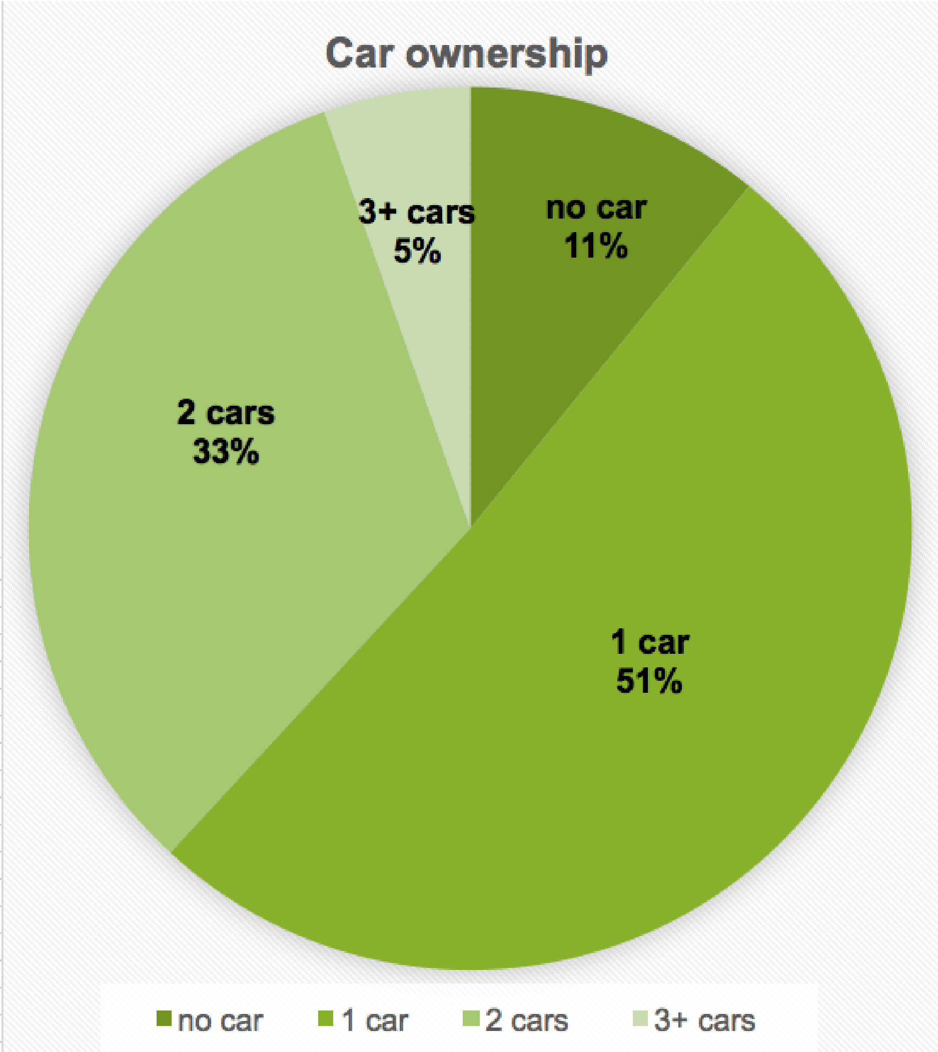

Figure 1. Number of cars Dutch households owning

In consistent with the previous literatures, urbanity is found to have obvious influence on car ownership in the household. Households which do not own any car are 5 times more likely to live in the most central area. Households owning 1 car are slightly more distributed in slightly urbanized area, but the ones owning more than 1 car are much more distributed in less urbanized areas. More specifically, car ownership is the highest in the least urban area which reaches 95%, with 20 percent points higher than in the most urban area.

For education of the respondents, it is also found the higher the education of the respondent, the more likely the household will own one or more cars. Similarly, as one of the most important factor influencing car ownership, income is also found to have positive influence on household decisions to own a car. The car ownership rate reaches 97.5% in the highest income group, 29.4 percent points higher than the lowest income group.

As a dependent variable, most of the papers divided car ownership into different groups, some of which simply created two groups distinguishing households with cars and households without cars, while some other papers furtherly create more groups from the households with cars, which shows households with 1 car, 2 cars, etc. In this dataset, respondents were given 10 answers (excluding unknown) based on the survey question of car ownership – from households with 0 car, 1 car, to households with 9 or more cars. Therefore, just like most literatures did, car ownership will be analysed by a dummy variable *Car_Yes* to represent households with cars and households without cars. However, households without cars only account for 11% of all the households; in this way, it is very difficult for policy makers to work towards a goal hoping that less households are owning cars. So only focusing on this specific small group will not bring much value since it is less likely that households decide to own no cars. Therefore, the study will furtherly use another dummy variable *Car_more* to distinguish the households with 1 car and households with more than 1 car.

3.2.2 Main variables

3.2.2.1 Urbanity – Urban1_d1 & Urban2_d1

Built environment, as a very important factor influencing car ownership, has many different perspectives. Generally speaking, 2 methods are mostly used to measure the effect of built environment. Some researcher estimated this effect from an urban/city point of view, in which most of the time they included an urban dummy variable, while some other papers studied the effect from 5Ds (Density, Diversity, Distance, Design, Destination) perspectives. But these 5 types of variables are extended from the most basic rural/urban concepts and to some extent correlated with each other. For example, most of the time urban areas are found to have higher population density, diversified activities, shorter distance to activities, and easier accessibility of destination.

Among all the respondents, it is found 30% people are living in very urbanized or least urbanized area, and this is not changing much over the years, with slightly less people living in the least urbanized area in 2013 compared to 2010 *(See figure 2).* Interestingly, when exploring the relationship between the urbanity and household income, it is found that slightly urbanized area is the most favourable choice of almost all the income groups, and in the most urbanized area, lowest income group (in total 10 groups) accounts for the largest part which is 16.6%. Similarly, it is also found that the largest share of people living in the most urbanized area is the lowest education group. While it is also found out that the highest education group also accounts for a very large share in the most urbanized area, only 0.4 percent points lower than the lowest education group.

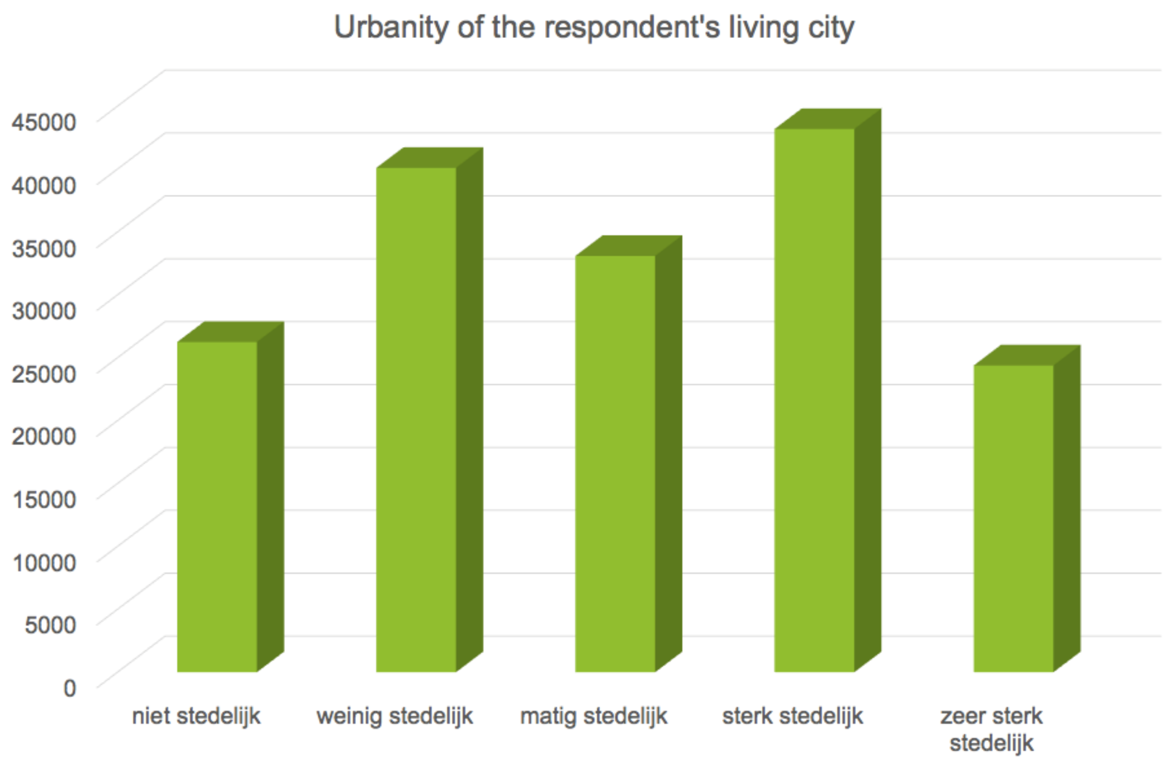

Figure 2. Urbanity of the respondent's living city

In highly urbanized area, living space is always quite limited, so it is expected that bigger households are more likely to live in less urbanized areas. This is in consistent with the expectation that for a single person household, slightly urbanized area and strongest urbanized area would be the most attractive place for them to live in; while for households with 2-4 persons, slightly urbanized area and less urbanized area are the most favourable choices. However, for households with more than 4 persons, it becomes more likely they are living in less urbanized area or even the least urbanized areas.

In this paper, the most basic and representative concept – urban/rural is chosen to show the effect of built environment. In the dataset, there are in total 5 categories[1] representing the urbanity degree from the least urbanity to the most urbanity. As most papers did, in this study, an urban dummy variable will be used for analysis. According to US Census Bureau, urban area is defined as a territory that has an average density of at least 1,000 inhabitants per square mile (United States Census Bureau, 2010). In Europe, similarly Eurostat (2011) use similar range to define city, which is 1,500 inhabitants per km^2. In the dataset selected, urbanity is measured by address density, which could be derived from using population density divided by 2 or 2.5. If using 1,500 as population density, then we have the address density at around 600 to 750 per km^2. In this way, we are going to define the urban dummy with two different cut-off points: 1) above 500 addresses per km^2 – *Urban1_d1*, which accounts for 84% of the sample or 2) above 1000 addresses per km^2 – *Urban2_d1,* which accounts for 60%. In general, the urban dummies are expected to have a negative influence on car ownership, so car ownership will decrease more in urban areas compared to rural area.

3.2.2.2 Public transport – PT_avail

As another main focus of many papers, public transport is studied from both accessibility and quality perspectives. Some papers include the public transport as a distance factor of built environment and the effect is always found quite strong, so quite another amount of papers study it as an independent public transport factor. No matter how public transport is classified, most papers estimate the accessibility effect instead of quality effect, mainly due to easier data source and more objective results.

Public transport accessibility is mostly measured by calculating the distance to the nearest bus, metro, or train stop, or the number of stations/stops within the neighbourhood. Some papers also directly ask the respondents to think about how their access to public transport is. However, this is quite subjective so that the answers are most

[1] zeer sterk stedelijk: gemiddelde oad van 2500 of meer adressen per km^2; sterk stedelijk: gemiddelde oad van 1500 tot 2500 adressen per km^2; matig stedelijk: gemiddelde oad van 1000 tot 1500 adressen per km^2; weinig stedelijk: gemiddelde oad van 500 tot 1000 adressen per km^2; niet stedelijk: gemiddelde oad van minder dan 500 adressen per km^2

likely to be biased due to imbalanced knowledge of people and different perceptions of their feeling.

In this paper, public transport accessibility is going to be our second main variable (*PT_avail*), which is selected from KpVV and merged into OViN dataset by using the municipality names as a comparable variable. *PT_avail* estimates the ratio number of inhabitants in 2013 in each municipality who have a train station or bus stop within reasonable distances. The reasonable distances here are seen as 500 meters for a bus stop and 2000 meters for a train station. In the data, 411 municipalities are estimated, among which 5 cities were dropped during merging. It was found the number of people with public transport nearby increased from 91.7% in 2003 to 92.4% in 2015.

According to the data in the Netherlands, it appears that more than 92% people are living in a place with public transport nearby. And there are even 7 areas showing a maximum rate of 100%, which including Gouda, Leiden, Maassluis, Sliedrecht, Papendrecht, Hardinxveld-Giessendam, and Rozendaal. This means in the above areas all the respondents have bus or train access in the neighbourhood. In the largest cities like Amsterdam and Rotterdam, the ratios are reaching 99.84%, Eindhoven and Utrecht with 99.53% and 99.19% respectively. While among all the cities, Haaren appears to be the only one with access to public transport lower than 50%, which is only 46%. *PT_avail* is expected to have a negative influence on car ownership. So better public transport will decrease the possibility of households to own one or more cars.

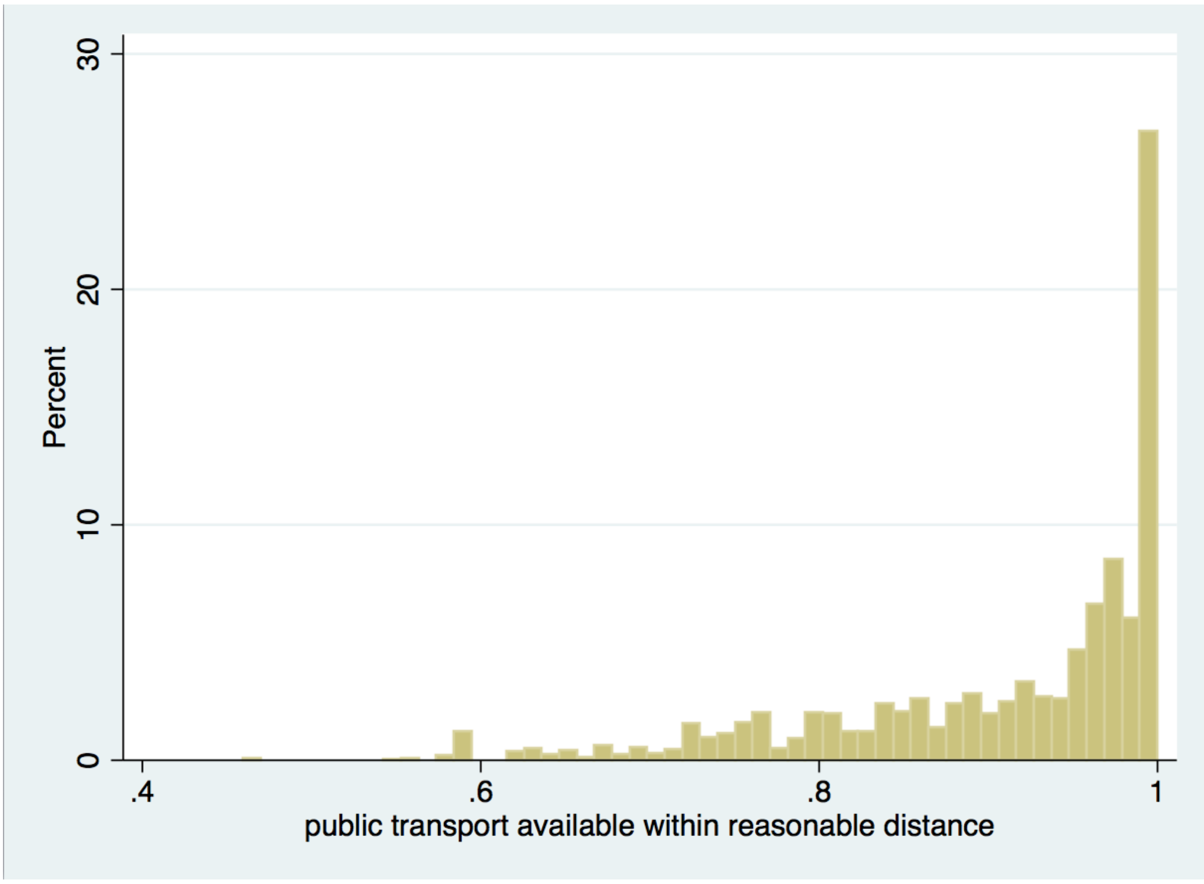

Figure 3. Public transport avaiable within reasonable distance (in percent)

3.2.2.3 Interaction variable: BExPT

Built environment and public transport have already been studied thoroughly by many papers in many countries. However, seldom of papers are studying the interaction effect between these two factors. As mentioned in the previous section, this study will focus on the interaction effect between build environment and public transport. Therefore, interaction variables (*BExPT1 & BExPT2*) are generated, to investigate whether the public transport factor will strengthen the effect of built environment on the car ownership within a household. We expect this variable significantly influencing the urban effect on car ownership.

3.2.3 Control variables

Results from many researches also show the significant influences of demographical factors on car ownership, like some household characteristics including household composition and household income. In this paper, these factors will be controlled.

3.2.3.1 Household composition: HHPers, HHChild

In the Netherlands, it is found more than 96% households are composed with 5 or less than 5 persons. Most households are having 2 persons, which accounts for 31% of the total households, followed by 4-person households with 26%. From 2010 to 2013, single-person households were found to be increased by 1.2 percent points. Households with 2 persons or 3 persons were also found to be increased slightly by 0.9 and 0.2 percent point respectively. However, the share of any other larger households tend to decrease over the years.

Mostly, two methods are used to measure household composition. Some papers distinguished the households into groups like singles, couples, couples with children, etc, while some other papers measured the number of members or adults within a household. This paper will use total number of persons within a household (*HHPers*), and number of children (*HHChild*) within a household for analysis. The number of children here refers to children below 11 years old (11 included), since elder children (teenagers) are more independent and responsible for their own activities than the younger ones. As more people or children in a household will have higher needs of car using, we expect household size, and the numbers of children within a household to have positive influences on car ownership.

3.2.3.2 Household income: HHIncG

As one of the strongest effect on car ownership, household income will also be controlled here. The measurements of household income are more diversified, including total household income, disposable household income, and total household expenses, and even occupations. This dataset includes quite a lot of different income variables including disposable income, standardized disposable income, and standardized disposable income in 10 groups. This paper is going to use standardized disposable household income in 10 groups (*HHIncG*) as a proxy, which have even observations in each group so that can be seen as a continuous variable. With higher household income, car ownership is expected to be higher.

In the dataset, after standardizing the household disposable income, it was found most households are having 20,000 to 30,000 (in euro) disposable income a year, which accounts for 38% of the sample, followed by a 32% of households having 10,000 to 20,000 euro a year. From the year 2010 to 2013, it is also found out households are generally having more disposable income.

3.2.4 Omitted variables

Education is a focus of many papers as well, since they think higher educated people will have higher income or higher possibility to get into labour market so a higher need of mobility. Therefore, higher education is expected to have a higher possibility for the household to own a car or having more cars. Education effect on car ownership is mostly focused on the education situation of the head of household. However, with more equal relationship among people, the concept of “household head” is becoming very vague. Moreover, in the dataset, there are no questions hinting whether the respondent is a household head. Therefore, it is difficult to link the education level of a random respondent with the car ownership in a household level in this model. Therefore, variable education will not be used in the model.

As we concluded in the previous chapter, many researchers prefer using 5Ds variables for built environment analysis. Among the 5Ds, distance to public transport is estimated as the effect of public transport; density is reflected in the urban dummy variable, while the else will not be used due to lack of data. However, they are not of great importance since design, diversities, and destination accessibilities can be more or less reflected in the urbanity information. Public transport quality will also not be included in the model. The estimations of quality are mostly very subjective, so the evaluation of this variable is also less reliable. Individual characteristics such as gender, occupation will not be used in this paper, since gender is only found to have a vague and small effect, and occupation can mostly be reflected in income as well. Age and costs of car ownership will not be included neither due to lack of data.

3.3 Methodology

3.3.1 Model

With dependent variable being dummies with binary outcomes, Linear Probability Model (LPM), Logit Model, and Probit Model are all suitable for analysis. However, the results of Logit Model or Probit Model are not that intuitive to understand or interpret, so a Linear Probability Model is developed to measure how much car ownership depends on built environment and public transport, with controlling household characteristics.

The models are specified as

Pr(Car_Yes =1) = F (Urban_d, PT_avail, BExPT, HHPers, HHChild, HHIncG, ε)

Pr(Car_more = 1) = F (Urban_d, PT_avail, BExPT, HHPers, HHChild, HHIncG, ε)

where

Car_Yes	dummy – households owning cars (or not owning cars)
Car_more	dummy – households owning more than 1 car (or owning only 1 car)
Urban1_d1	dummy – urban area (above 500 addresses per km^2)
Urban2_d1	dummy – urban area (above 1000 addresses per km^2)
PT_avail	public transport variable – share of inhabitants in the municipality with train/bus access within reasonable distance
BExPT1	interaction effect – Urban1_d1 * PT_avail
BExPT2	interaction effect – Urban2_d1 * PT_avail
HHPers	demographic variable – number of people living in a household
HHChild	demographic variable – number of children living in a household
HHIncG	demographic variable – standardized disposable income in a household in 10 groups
ε	error term

However, when using LPM several potential problems will probably arise: (1) heteroskedasticity: the binary outcome cannot be the same for all the observations, therefore standard error would be wrong; (2) errors are not normally distributed: it is difficult for residuals to have normal distribution since they are only free to take on two possible values; (3) unbounded predicted probabilities: there is no limitation for the predicted possibility to fall out of 0-1 range, while this will not be a serious issue if there are not too many predicted values falling out of range.

3.3.2 Variables and correlations

Some general information of the variables *(see table 2)* and the correlation table is attached here. No high correlations are found between the variables. In both the two models used, it is found the correlation between public transport and urban dummy, and correlation between size of households and number of children within a household are having a correlation higher than 0.6 *(See table 3 and 4)*. While this paper is going to use a large dataset with 166,937 observations, so it is assumed the correlation effect will be handled well without causing serious problems like invalid or biased results.

Table 2. Variables descriptions (Car_Yes N=166,937 or Car_more N=148,776)

Variable	**Description**	**Mean**	**SD**
Car_Yes	dummy – households owning cars (or not owning cars)	0.891	0.311
Car_more	dummy – households owning more than 1 car (or 1 car)	0.428	0.495
Urban1_d1	dummy – urban area (above 500 addresses per km2)	0.843	0.364
Urban2_d1	dummy – urban area (above 1000 addresses per km^2**)**	0.603	0.489
PT_avail	public transport variable – share of inhabitants in the municipality with train/bus access within reasonable distance	0.910	0.101
HHPers	demographic variable – number of people living in a household	3.010	1.423
HHChild	demographic variable – number of children living in a household	0.612	0.967
HHIncG	demographic variable – standardized disposable income in a household in 10 groups	5.496	2.869
BExPT1	interaction effect – Urban1_d1 * PT_avail	0.772	0.356
BExPT2	interaction effect – Urban2_d1 * PT_avail	0.560	0.478

Table 3. Correlations (dep. var. Car_Yes)

	Car_Yes	Urban1_d1	Urban2_d1	PT_avail	HHPers	HHChild	HHIncG
Car_Yes	1.000						
Urban1_d1	-0.080	1.000					
Urban2_d1	-0.135	0.532	1.000				
PT_avail	-0.134	0.486	0.705	1.000			
HHPers	0.277	-0.041	-0.070	-0.070	1.000		
HHChild	0.126	-0.008	-0.013	-0.018	0.641	1.000	
HHIncG	0.275	0.011	0.005	0.003	-0.004	-0.143	1.000

Table 4. Correlations (dep. var. Car_more)

	Car_more	Urban1_d1	Urban2_d1	PT_avail	HHPers	HHChild	HHIncG
Car_more	1.000						
Urban1_d1	0.064	1.000					
Urban2_d1	0.109	0.527	1.000				
PT_avail	0.104	0.480	0.697	1.000			
HHPers	-0.283	-0.025	-0.044	-0.043	1.000		
HHChild	-0.106	0.000	0.001	-0.004	0.633	1.000	
HHIncG	-0.265	0.036	0.045	0.044	-0.087	-0.188	1.000

Chapter 4. Estimation results

Mentioned in the previous chapter, this paper will build up LPM models. The models in 4.1 will investigate car ownership being a dummy representing households with cars and households without cars. While since there are only 11% households which do not own a car, this paper will study furtherly among the households with cars. Therefore, the models in 4.2 will analyse the determinants on car ownership with a dummy representing households with one car or with more than one cars.

4.1 Car ownership – with car v.s. without car

In the first section, car ownership will be distinguished between households with cars and households without cars. Can be seen in the below pie chart, only 11% households do not own any car, while 89% households have their own cars *(see figure 4)*. Table 5 shows the analyzed results.

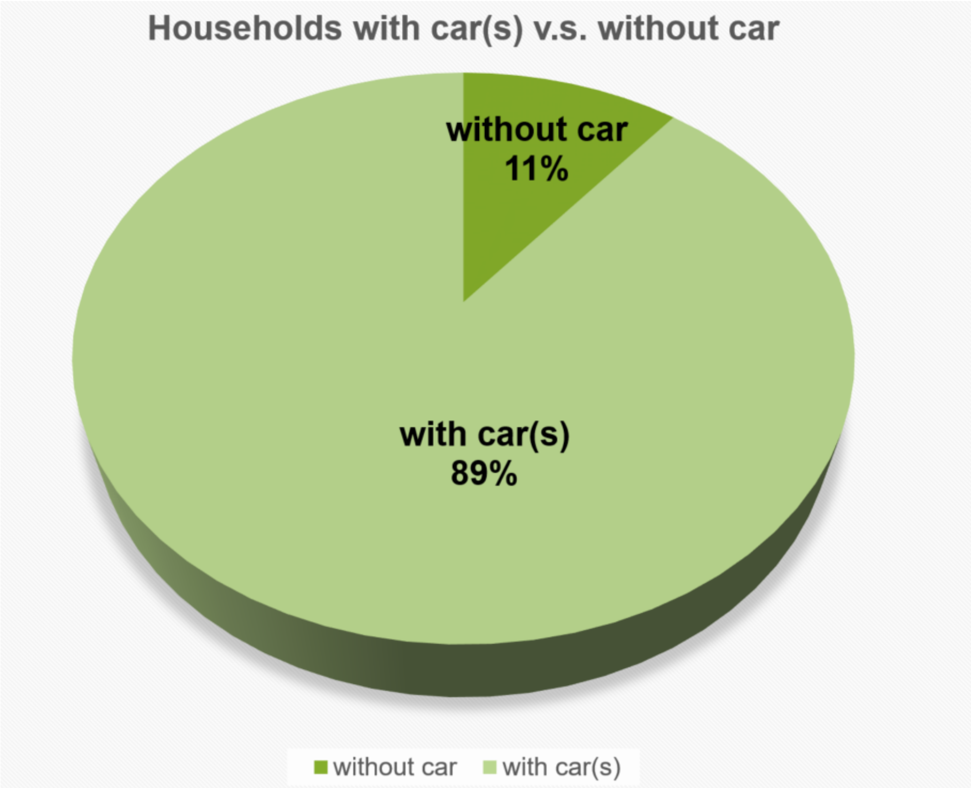

Figure 4. Households with car(s) and households without car in the Netherlands

4.1.1 With broadly defined Urban dummy & interaction effect

Model 1a and 1b show the results when defining urban areas with address density higher than 500 per km^2, with Table 1b including the interaction effect.

From Model 1a, all the variables are found to be at 99% significant level, and most variable effects are of expected sign except for *HHChild*. Urban is found to have small negative influence on the households' decision to own a car. Households living in urban are 1.8% less likely to have a car/cars than households living in rural areas. Also as expected, public transport is found to be have a great negative influence, that households living in a municipality with the highest public transport accessibility (which is 100% here, means all households in this municipality are having public transport nearby within reasonable distance, see 3.2.2.2 for details of public transport availability) nearby are having a 17.5% lower chance to own a car/cars themselves than the households living in a municipality with the poorest public transport accessibility (which is 46% here, means only 46% households in this municipality have public transport within reasonable distance), i.e. households from Haaren.

Among the household characteristics, household size is found to have positive effect, one more person in a household will increase the possibility to own a car by 6.1%. So if a single person's household is increasing to a 3 person's household, the possibility for this household to own a car/cars will increase by 12.2%. Income is also found to have positive influence on car ownership, but not that much: one level's increase of the household income will increase the possibility to own a car(s) by 3%. Therefore, the households in richest group will have 30% higher possibility to own a car/cars than the lowest income households. While interestingly, the effect of number of children within a household is in opposite to the expectation and previous studies. It is showing a small negative influence, where the reason might be most households with more children are found to be lower income households.

Model 1b shows the results including interaction effect, which is significantly negative. The difference between urban and rural with the same public transport accessibility depends on the accessibility degree of the public transport. More specifically, the interaction effect shows us the effect of public transport is much bigger in magnitude in urban area than in rural area. Compared to a municipality with 46% (worst) public transport accessibility in the Netherlands, a municipality with 100% public transport accessibility will make an urban household to be 20.6% less likely to own a car/cars *(See figure 5)*, and a rural household 1.1% less likely to own a car/cars. Therefore, it can be seen that the public transport effect largely strengthens the urban effect, while rural effect is barely influenced. From the perspective of urbanity, the results show that with 100% public transport accessibility, urban households are 8.4% less likely to own a car/cars than rural households; while with 46% (worst) public transport accessibility, urban households are 8.2% more likely to own a car/cars than rural households. In this way, not only the magnitude of urbanity depends on the degree of public transport, but also the direction of impact of living in a rural area depends on the public transport availability.

Therefore, it is found that although urban itself only has a relatively small effect (1.8%) on the car ownership of households, the effect becomes 10 times stronger after introduced the interaction factor in the model. Moreover, the interaction effect becomes much stronger when a city is more urbanity. This a valuable result for relevant policy makers because improving public transport is much easier than developing a better build environment. Effects of the other household variables remain at a similar level.

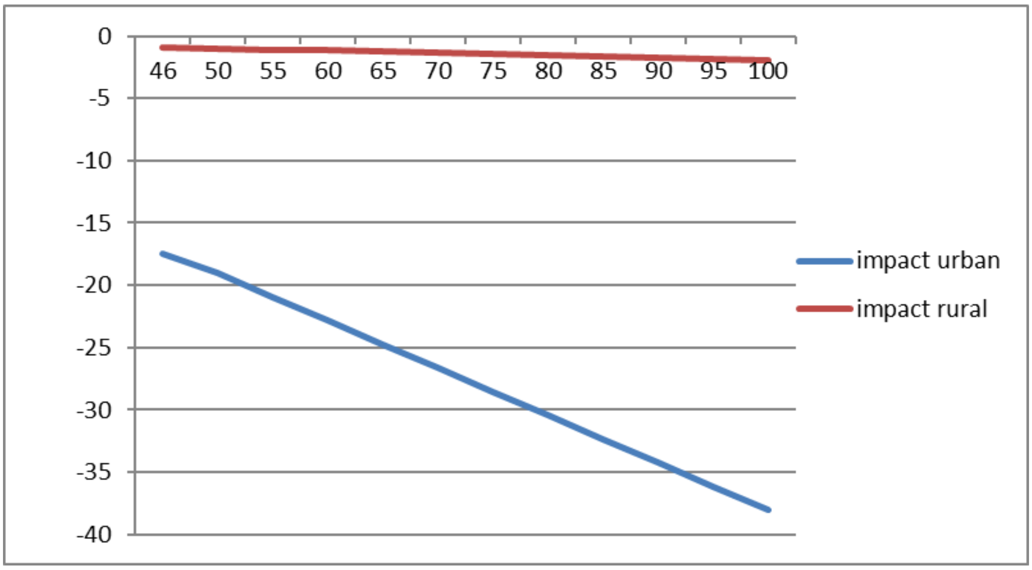

Figure 5. Interaction effect – Model 1b

Table 5. Results 1 (Car_Yes as dependent variable)

	Model 1a			Model 1b			Model 2a			Model 2b		
	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
Urban1_d1	-0.0181	0.0022	***	0.2770	0.0179	***						
Urban2_d1							-0.0453	0.0020	***	0.5213	0.0214	***
PT_avail	-0.3242	0.0079	***	-0.0196	0.0200	*	-0.2014	0.0097	***	-0.0573	0.0111	***
BExPT1				-0.3611	0.0218	***						
BExPT2										-0.6072	0.0228	***
HHPers	0.0615	0.0006	***	0.0612	0.0006	***	0.0610	0.0006	***	0.0604	0.0006	***
HHChild	-0.0056	0.0010	***	-0.0053	0.0010	***	-0.0051	0.0010	***	-0.0048	0.0010	***
HHIncG	0.0298	0.0002	***	0.0298	0.0002	***	0.0298	0.0002	***	0.0297	0.0002	***
_cons	0.8564	0.0070	***	0.6142	0.0162	***	0.7578	0.0084	***	0.6414	0.0094	***
N	166,937			166,937			166,937			166,937		
Prob > F	***			***			***			***		
R-sqr	0.1667			0.1681			0.1689			0.1724		
Adj R-sqr	0.1667			0.1680			0.1689			0.1724		

*Note: dep. var. is car dummy (household has car); *p<0.05, **p<0.01, ***p<0.001*

4.1.2 With narrowly defined Urban dummy & interaction effect

Model 2a and 2b show results when defining urban areas with address density higher than 1000 per km^2, where Model 2b including the interaction effect.

Similarly, in Model 2a without interaction factor, all the variables were found to have highly significant results at 99% level. For household size, number of children in a household, and household income, the magnitudes are remaining almost the same as in model 1a. While for the narrowly defined urban dummy variable, the negative effect is found to have 2.7 percentage points larger than using the broadly defined urban, which shows urban households are 4.5% less likely to own a car compared with rural households. Therefore, it seems no matter how urban is defined, it is always a very important factor determining car ownership, while the magnitude of the influences might change a bit with different definitions. Compared to broadly defined urban, this result furtherly show higher urbanity has bigger negative influence on car ownership. Except for this, public transport accessibility was also found to have significantly negative effect, households living in a municipality with the best public transport are having a 11% lower chance to own a car/cars compared to the households living in a municipality with the poorest accessibility of public transport. This is 6.7 percent points lower than the effect in model 1a, where the reason might be there is less differences of the public transport accessibility when we include more areas as rural.

In Model 2b, it can be seen that after including the interaction effect, the influences of household size, number of children, household income were barely changed. While the interaction factor is still significant and even much stronger. If the public transport accessibility in a municipality is improved from 46% to 100% *(See figure 6)*, an urban household will be 35.9% less likely to own a car/cars, while for rural households the effect is only 3.1%. In this way, with a much narrowly defined urban dummy, a better public transport has stronger influence on urban effect of decreasing the possibility for households to own a car/cars. Therefore, with different definitions of urban dummy, the results furtherly show that with urban density being higher, their effect on car ownership is much stronger.

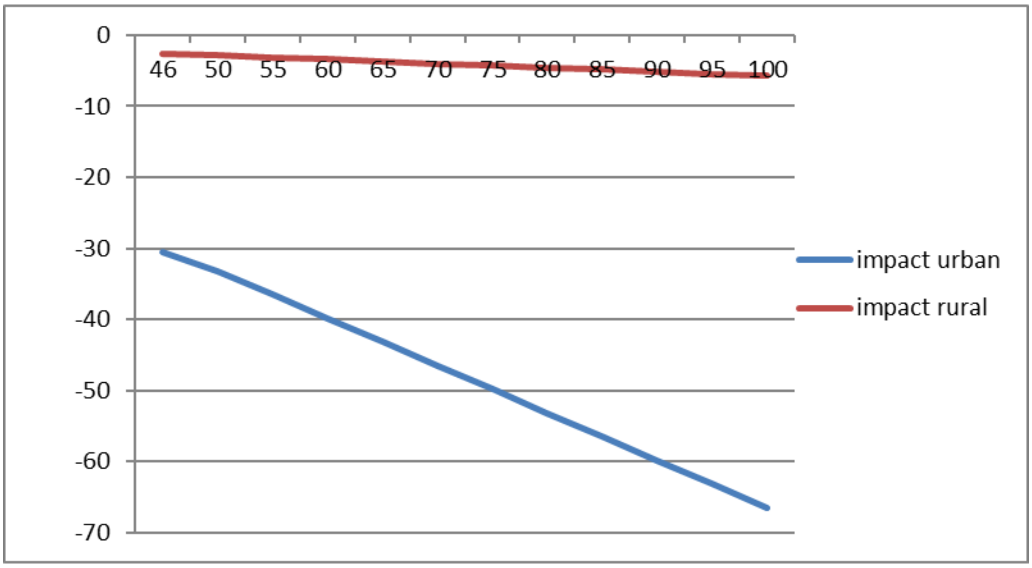

Figure 6. Interaction effect – Model 2b

4.2. Car ownership – one car v.s. more than one car

As mentioned before, households without any car account for a relatively small group in the sample; therefore, the study drops the households without cars and furtherly creates a second dummy variable divided the households with only one car, and households with more than one car. Among the households with cars, it can be seen from the below graph *(see figure 5)* that 57% of households are owning only one car, while the rests are owning more than one cars. Results are shown in *table 6*.

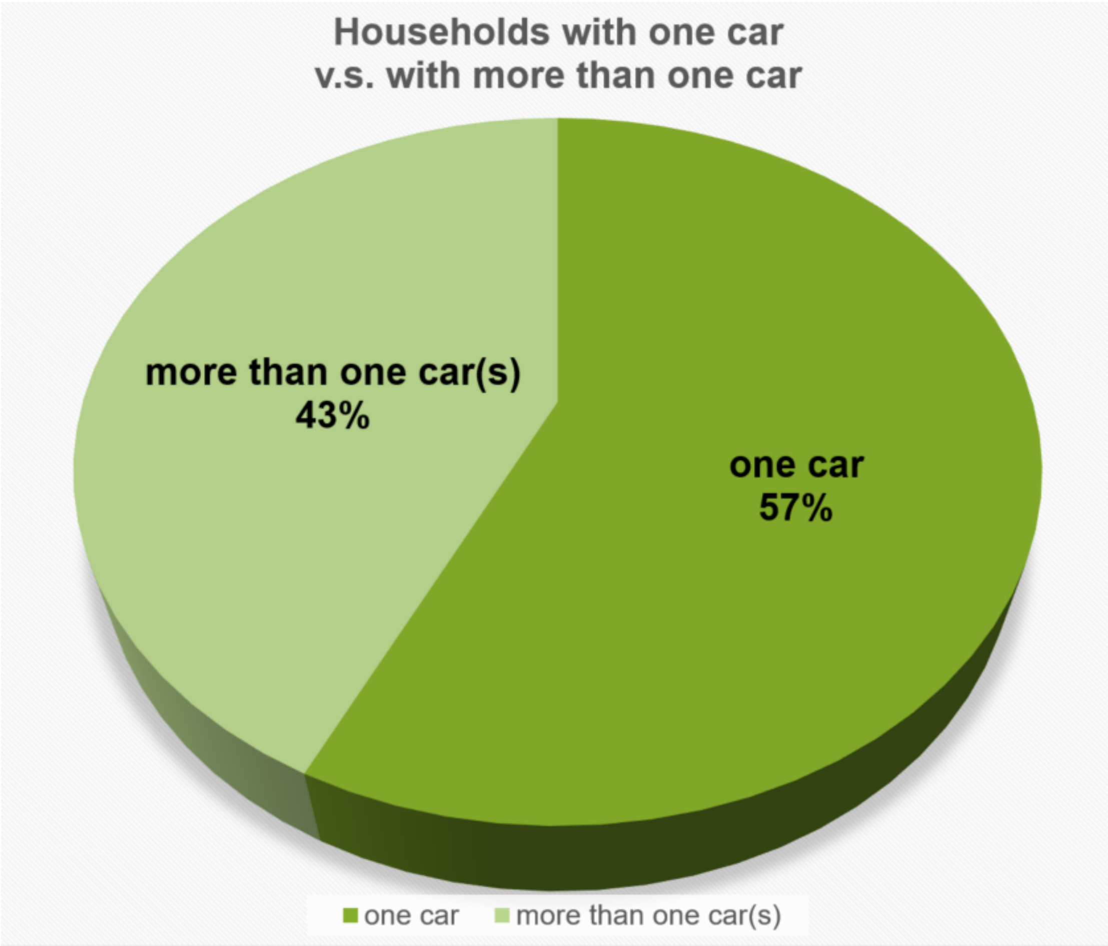

Figure 7. Households with one cars and households with more than one cars in the Netherlands

4.2.1 With broadly defined Urban dummy & interaction effect

Model 3a and Model 3b show the results when using urban dummy defined with address density higher than 500 per km^2, where Model 3b including the interaction effect.

With the signs being unchanged, it is found out all the variables are at 99% significant level and have much stronger effect than Model 1a and Model 1b. The effect of household size is 100% higher compared to the results from Model 1a that one more person in a household will increase the possibility for this household to own more than one car by 12%. So if a household is growing from one person to 3 persons, the possibility to own more than one car would be increased by 24%. Number of children is also found to have much stronger effect, with a 2.7% compared to 0.6% in Model 1a. Similarly, household income also has stronger effect, where one higher income group can increase the possibility for households to buy more than one car by 5%. So the highest income households are 50% more likely to own more than one car than the lowest income households.

Most importantly, urban and public transport effects are also found to be more obvious. Households living in urban areas are 3% less likely to own more than one car. The reason could be in urban areas there are more convenient accessibilities to different activities, so less cars are needed. It could also be difficulties in finding parking spaces and higher parking prices to own more than 1 car. Compared to Model 1a, public transport accessibility is found to have stronger effect on the decision of households to own more than one car as well. A household living in a municipality with poorest public transport accessibility (in this case Haaren for example, where 46% households do not have public transport nearby within reasonable distance) is 24% more likely to own more than one car compared to the household living in a municipality with the best public transport available area (where all the households have public transport nearby within reasonable distance).

Similarly, after introducing the interaction factor, it can be seen in Model 3b the effect of household characteristics barely changed. In this case, if public transport accessibility in a municipality is improved from 46% to 100% *(see Figure 8)*, urban households will be 27.7% less likely to own more than one cars, while rural households will be 4.3% less likely to own more than one cars. Therefore, again only in urban area, a better access to public transport strongly decreases the possibility for households to own more than one car. Although urban itself only has a relatively small effect on the number of cars households owning, the effect becomes much stronger after introduced the interaction factor in the model.

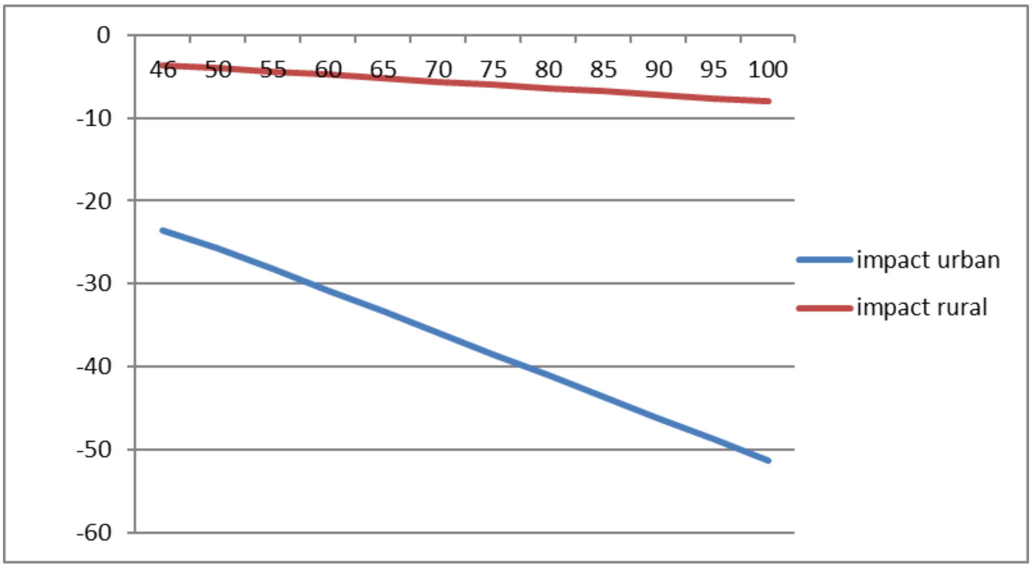

Figure 8. Interaction effect – Model 3b

Table 6. Results 2 (Car_more as dependent variable)

	Model 3a			Model 3b			Model 4a			Model 4b		
	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
Urban1_d1	-0.0301	0.0036	***	0.3235	0.0291	***						
Urban2_d1							-0.0707	0.0033	***	0.4104	0.0355	***
PT_avail	-0.4431	0.0130	***	-0.0804	0.0324	*	-0.2577	0.0159	***	-0.1401	0.0181	***
BExPT1				-0.4327	0.0354	***						
BExPT2										-0.5158	0.0379	***
HHPers	0.1212	0.0011	***	0.1210	0.0011	***	0.1206	0.0011	***	0.1202	0.0011	***
HHChild	-0.0272	0.0015	***	-0.0269	0.0015	***	-0.0264	0.0015	***	-0.0262	0.0015	***
HHIncG	0.0511	0.0004	***	0.0512	0.0004	***	0.0512	0.0004	***	0.0513	0.0004	***
_cons	0.1953	0.0115	***	-0.0935	0.0262	***	0.0440	0.0138	***	-0.0518	0.0154	***
N	148,776			148,776			148,776			148,776		
Prob > F	***			***			***			***		
R-sqr	0.1775			0.1783			0.1796			0.1806		
Adj R-sqr	0.1774			0.1783			0.1796			0.1806		

*Note: dep. var. is dummy (household has one car); *p<0.05, **p<0.01, ***p<0.001*

4.2.2 With narrowly defined Urban dummy & interaction effect

Model 4a and Model 4b show the results when using urban dummy defined with address density higher than 1000 per km^2, where Model 4b including the interaction effect.

Similarly, compared with the results in Model 2a, all variables were found to be at 99% significant with much stronger effects. In Model 4a, households living in urban area are also found to have more obvious effect, which is 7% less likely to own more than one car than rural households. This was also found to be 4 percent points higher compared to the broader defined urban area in model 3a. The results also show that with households living in an area with best public transport accessibility is 14% less likely to owning more than one car than households living in an area with poorest public transport accessibility.

In Model 4b, it can be seen the household characteristics effect are remaining at a same level compared to in Model 4a, while the interaction effect was found to be significantly important again. So if the public transport accessibility in a municipality is improved from 46% to 100% *(See figure 9)*, urban household will be 35.4% less likely to own more than one cars, 5 times comparing with rural households (7.6%). Therefore, considering the number of cars a household is owning, a better public transport always strengthens the effect of urbanity to a large extent, no matter how urban is defined.

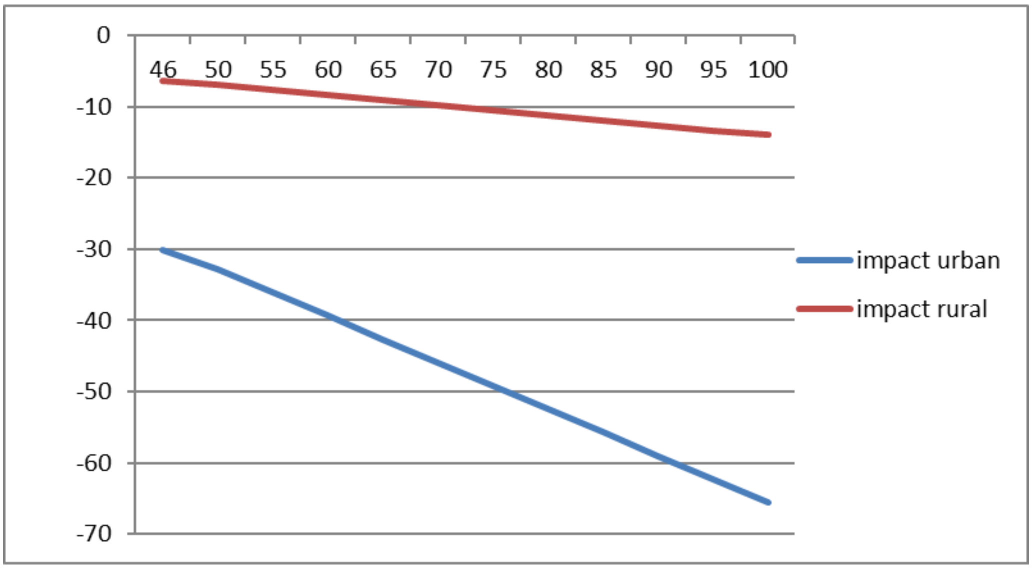

Figure 9. Interaction effect – Model 4b

Chapter 5. Conclusion

By using the data from the Netherlands, this paper developed a Linear Probability Model for the determinants of car ownership, focusing on build environment, public transport, and their interaction effect by controlling household characteristics. Therefore, the paper firstly investigates if the above factors will influence the choice for households to own a car or not. However, in the Netherlands it is found that only 11% households are without any car, which to some extent means people are not that sensitive in changing the decisions from owning car(s) to not owning a car. Therefore, the paper furtherly divided the households with cars into two groups: households with only one car and households with more than one car. In this way, it can provide more valuable results for policy makers so that they know if it is effective to decrease the car ownership in a household.

Results show that all the factors are significantly important. Build environment is found to have very small effect on car ownership. However surprisingly, the effect of households living in an urban area is found to be much strengthened by adding the interaction factor with public transport. As build environment is the main focus, the paper takes different cut off points to define the urban dummy used. Results show that no matter how the urban dummy is defined, it is always showing significant effect. And the narrowly defined urban dummy has stronger effect than the broadly defined one, which furtherly shows with urbanity being higher, the effect is becoming stronger. Among all the variables, public transport accessibility is found to have the strongest influence on car ownership, except for the interaction factor. During the control variables, household size and household income are found to have small positive effect, while in contrast the number of children within a household is found to have negative effect, which is different from expectation.

The results are very meaningful to some policy implications to the government. In urban areas, a better public transport will significantly and highly decrease the likelihood of households to own a car or more than one cars. So in order to decrease car ownership, an effective policy for urban authorities might be build up or improve the public transport accessibility.

However, there are several limitations of this study. Firstly, due to the data limitation, the study is only based on one country – the Netherlands. However, just like the other European countries, most cities in the Netherlands keep old looks due to historical reasons so that the city designs are also still old and street networks are quite narrow. This is quite different if compared with modern American cities. Therefore, with the main variable being the built environment, the results might not be applicable to some other countries with much different built environment such as America. So future study can investigate more countries and compare to see how the determinants change among different countries. Future study can also include a much broader scope with a larger perspective, such as investigate the overall car ownership in the European Union. Secondly, the study is using a Linear Probability Model to analyse the results. However, drawbacks like heteroscedasticity and unbounded predicted probabilities might influence the accuracy of the results. Therefore, future study can explore the results with other models such as Logit model or Probit model. Thirdly, due to the limited data, the study is investigating by focusing on the year 2013. So comparisons and changes of the variables during different time cannot be detected. In this case future study can include more years in the study to analyse the changes and trends during the time. Finally, for built environment, the paper is only studying one variable – if households live in urban or not. Moreover, individual factors like education, occupation, and gender were also omitted. In this way, future studies can have more detailed analysis by including more built environment factors (5Ds variables: Density, Diversity, Distance, Design, Destination) and individual characteristics.

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