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How does the accessibility of daily amenities influence household car ownership in Dutch urban neighbourhoods?

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Abstract

Following the shifted transport policy emphasis and investment away from the car (Boarnet, 2013 in Elldér et. al., 2022) and the argued ability of land-use decisions to considerably influence travel choices and transportation options (Stevenson et. al., 2016), this research aims to explore *how the accessibility of daily amenities (in terms of distance) influences (household) car ownership in Dutch urban neighbourhoods.* Using an Ordinary Least Squares cross-sectional and a Fixed Effects panel-based regression with a rich set of neighbourhood controls, the relationship between daily amenity distance ((overarching) factor or distinct type) and household car ownership in Dutch urban neighbourhoods is estimated, utilizing key figures and proximity statistics provided by Centraal Bureau voor de Statistiek. While the results indicate that, compared to other neighbourhoods and over time, there is a robust statistically significant positive association between (the general) distance to daily amenities and household car ownership, found effects are fairly small (especially considering "realistic" distance decreases). For policymakers aiming to drastically decrease car levels, accessibility related policies are therefore unlikely to results in the desired (large) effects (although large distance reductions or combinations can offer a solution). If the built-environment nevertheless wants to be used to reduce car ownership, the results indicate that while almost all daily amenity distances ((overarching) factor or distinct type) can be statistically significant and positively associated with household car ownership, distance reductions to *children related facilities*, as a group, are associated with largest and robust car ownership reductions. The large differences between models for individual/distinct distances moreover imply that possibilities for an overall decrease (both comparing neighbourhoods and comparing over time) in household car ownership are limited to distance reductions related to *general practice, pharmacy* and *performing arts* (the latter also being robust). Non-linearities found in terms of (i) diminishing sensitivity and a (ii) negative interaction effect with alternative mobility distance additionally indicate that daily amenity accessibility effects on household car ownership are larger when (i) distances are already small, and (ii) the distance towards alternative mobility is smaller.

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1. Introduction

In almost a century, the number of passenger cars in the Netherlands has increased from 41 thousand in 1927 to 8.5 million in 2019, which amounts to an increase of a generous factor of 200 (Oostvogels, 2019). Rising car ownership, however, is not a theme of the past and continues today. Compared to four years ago, the number of passenger cars has increased by 5.6 percent to 8.9 million (Centraal Bureau voor de Statistiek, n.d.-h) while projections indicate that the number of cars will increase further to approximately 9.5 million in 2030 (Monster, 2022).

Such high levels of car ownership are argued to be associated with increasing levels of car-based travel, in turn resulting in health and air quality problems (Handy et. al., 2005 in Potoglou and Kanaroglou, 2008). Accordingly, in the aim for sustainable urban development, many Western cities have shifted transport policy emphasis and investment away from the car while importance and mode share of walking, cycling and public transport have grown (Boarnet, 2013 in Elldér et. al., 2022). Such a shift (towards e.g., walking) can

(i) reduce negative effects associated with motorized vehicles, such as noise, emissions and congestion (Ellis et. al., 2016; Ribeiro and Hoffimann, 2018; Taleai and Amiri, 2017 in Fonseca et. al., 2022),
(ii) prevent various diseases (related to the physical activity associated with active travel modes) (Fonseca et. al., 2022),
(iii) improve recreational value and generate social capital (Gärling et. al., 2014 in Elldér et. al., 2022)
(iv) promote a more socially equitable transport system through its broad availability, in turn reducing vulnerability of disadvantaged people within car-dependent urban structures, such as children, elderly and low-income individuals (Southworth, 2005 in Elldér et. al., 2022).

Here, the Netherlands is no exception: While the city of Rotterdam aims for a mobility transition away from cars towards a cleaner, safter and greener city with good public transport connections and more space for pedestrians and cyclists (Gemeente Rotterdam, n.d.), other cities like Amsterdam, Groningen, Leiden and Utrecht share similar plans (Gemeente Amsterdam, n.d.; Folkers, 2021; Gemeente Leiden, n.d.; Gemeente Utrecht, 2022).

Based on the argued link between transportation and land-use (Medda and Boarnet, 2003 in Donaghy et. al., 2004) and the governmental acknowledgement of the ability of land-use decisions to considerably influence travel choices and transport options (Stevenson et. al., 2016), land-use policies aiming to reduce car dependency refer to, for example, the European *Compact City* (Aditjandra et. al., 2012). These policies follow the premise that by locating residential, work and service locations closer together, travel distances will become shorter, people will drive less and/or are more likely to travel by public transport, by bicycle and on foot (Aditjandra et. al., 2012). Matching the hypothesis of Zegras (2010):

All else equal, a household that can more easily reach destinations without using a car, will have less use for a car, and the probability of owning a car will be lower.

The existing literature on these built environment – travel relationships is argued to rarely consider local accessibility in detail (van Wee, 2016 in Elldér et. al., 2022). Generally, accessibility relates to the opportunities available to reach places where one can carry out important activities (Linneker and Spence, 1992 in Gutiérrez, 2001), reflecting the distance to/proximity of important amenities and public transport (Cervero et. al., 2009 in Fonseca et. al., 2022). However, it is argued that the presence of *specific* neighbourhood amenities (such as restaurants, shops, or schools) enables locally oriented daily living and directly influences travel to several everyday activities (Elldér, 2018; Handy, 2017 in Elldér et. al., 2022). Accordingly, from a policy (and planning) perspective, it is argued important to analyse the specific local amenities that influence where everyday activities are carried out (Elldér, 2018; Handy, 2017 in Elldér et. al., 2022). Similarly, for the design of proper policies to motivate more sustainable travel, understanding the determinants of household car ownership (which in turn is a key determinant of travel behaviour) is important (Nolan, 2010).

While detailed studies are performed regarding the supply (rather than proximity) of local amenities in Sweden (Elldér et. al., 2022), this research aims to fill the remaining gap in the existent literature (and provide an extension in terms of geographical location) by investigating the following research question:

How does accessibility of daily amenities (in terms of distance) influence (household) car ownership in Dutch urban neighbourhoods?

Here, the focus is thus on *daily amenities,* which are defined as everyday activities which could be conducted near home, by a large share of the population, on foot or by bicycle (Haugen, 2011 in Elldér et. al., 2022). Using a (i) cross-sectional and (ii) panel analysis allows for the estimation of the relationship between the distance to several daily amenities ((overarching) factor or distinct type) and household car ownership, both (i) *comparing between urban neighbourhoods* and (ii) *comparing over time within urban neighbourhoods*. While both analyses employ a rich set of controls, the panel-based Fixed Effects regression is, contrary to the cross-sectional "ordinary" OLS, additionally able to account for a range of possible (unobservable) biasing factors. In addition, considerations (or, non-linearities) on the form of the relationships, referring to (i) diminishing sensitivity for distance, and (ii) interaction with the accessibility of mobility alternatives, will be assessed.

When the formulated research question can be adequately answered, this study aims to provide insight not only into the importance of *daily amenity accessibility* in general (through usage of an aggregate overarching factor), but also into the hierarchy of importance for distinct groups and individual amenities. That is, if cities/policy makers want to reduce the number of cars in Dutch urban neighbourhoods, which local accessibility is most important, or results in the largest car ownership reduction. In addition, considering diminishing sensitivity and alternative mobility interaction hopes to provide insight into possible non-linear characteristics of these relationships.

The remainder of this paper is structured as follows: First, elaboration on the built environment – mobility link (and transportation/car ownership in general) is provided and hypotheses regarding the relationship between distance to daily amenities (aggregate and specific categories) and car ownership are determined (section 2). Then, the data and method used to estimate these relationships (and test the hypotheses) will be explained, followed by a discussion of the most important results (and possible limitations) (section 3 till 5, respectively). Subsequently, conclusions on the research question will be presented and related implications for policy will be suggested, followed by a critical reflection and suggestions for possible follow-up research (section 6).

2. Theoretical framework

Transportation, or travel, is generally argued to be a "derived demand" (Mokhtarian and Salomon, 2001 in Aditjandra et. al., 2012). That is, travel is commonly secondary to the activity it serves (Handy and Clifton, 2001; Meurs and Haaijer, 2001 in Elldér et. al., 2022), and thus derived from the desire to reach other places (Moktharian and Salomon, 2001 in Aditjandra et. al., 2012). These "other places", or purposes of journeys, are found (for the UK) to mainly relate to shopping, visiting friends, commuting and education (latter also including "escorting" to education), in that order. A hierarchy that has remained unchanged over 20 years (1986-2006) (Metz, 2010).

Considering this "derived demand" characteristic of travel, (all else being equal) destinations (i.e., "other places") in proximity should be preferred over distant ones (Handy and Clifton, 2001; Meurs and Haaijer, 2001 in Elldér et. al., 2022). Accordingly, *compact city* related policies are based on the premise that by locating residential, work and service locations in closer proximity to each other, trip lengths will decrease, and people will drive less (Aditjandra et. al., 2012) due to these shortened distances to amenities and because other transport modes, such as public transport, cycling or walking are more viable (Handy, 2017 in Elldér et. al., 2022). Destinations located within cycling or walking distance from home therefore make the compact city less susceptible to car dependency (Handy and Clifton, 2001; Naess et. al., 2017 in Elldér et. al., 2022). Matching the hypothesis of Zegras (2010): All else equal, a household that can more easily reach destinations without using a car, will have less use for a car and the probability of owning a car will be lower.

While the hypothesis of Zegras (2010) thus also suggests that car *usage* and *ownership* are related, a note further confirmed by

(i) Laviolette et. al. (2022) arguing for the extensive evidence that car ownership is positively associated with increased car usage and reduced usage of other modes, and
(ii) Handy et. al., (2005) in Potoglou and Kanaroglou (2008) who argue that high levels of car ownership are associated with increased car travel,

the remainder of the research will focus specifically on *(household) car ownership* as it is considered to be an important determinant of household travel behaviour (Nolan, 2010) which is interconnected with residential location (Scott and Axhousen, 2006 in Potoglou and Kanaroglou, 2008). Therefore, understanding how households, conditional on their residential location, choose the number of vehicles to own, is of great importance to urban planners and decision makers (Potoglou and Kanaroglou, 2008) for the design of proper policies to motivate more sustainable travel means (Nolan, 2010), matching the aimed contribution of this research.

However, by focussing on the relationship between (daily amenity) destination distance and car ownership, the question of why people would want to own a car in the first place is ignored (similar, but on a different subject, proposition suggested by Witte et. al., (2022)). Yet, Witte et. al. (2022) argue that this question is easy for many to answer: The car offers comfort, speed, luxury and a (relatively) safe way of travelling while, compared to cycling or walking, the car moreover makes it possible to easily (i) transport goods or passengers, and (ii) cover great distances. However, car ownership is also associated with less "practical matters": it is a status symbol (CROW, 2016), the prevailing social norm (Witte et. al., 2022) and the "creature of habit" plays its role (Witte et. al., 2022) (considering the latter, Nolan (2010) finds a high significance of state dependence in explaining household car ownership, suggesting that there is a strong persistence or habit in household car ownership between years). But also ecological awareness, fear of driving or strong affinity with cars can further explain differences in household car ownership (Witte et. al., 2022). Moreover, while travel demand is thus generally assumed to be derived demand, travel in itself is also believed able to carry positive utility, meaning that travel (under certain circumstances) can also be desired *for its own sake* (Mokhtarian and Salomon, 2001 in Aditjandra et. al., 2012). In practice, travel distance (to daily amenities) might therefore be *one of many factors* influencing whether or not to own a car (or, how many).

In order to establish hypotheses on the relationship between the proximity to daily amenities and car ownership in urban neighbourhoods (matching the focus of the study), the general relationship between the built-environment and mobility will be elaborated on (continuing on the latter's derived demand nature just discussed), followed by an identification of already found and quantified relationships. Ultimately, hypothesized direction of these relationships and related considerations will be determined and summarized into a conceptual framework.

2.1 The built environment – mobility link

While transportation and land-use are argued to be linked both ways (Medda and Boarnet, 2003 in Donaghy et. al., 2004), the adaptation of travel behaviour to urban form can be instantaneous (Donaghy et. al., 2004). Accordingly, governments are increasingly emphasizing the need to integrate land-use and transport planning, acknowledging the ability of land-use decisions to considerably influence travel choices and transport options (Stevenson et. al., 2016): Mixed-use development and densification (both are core strategies of the *compact city* (Bibri et. al., 2020)) are, for example, often favoured land-use policy interventions aiming to reduce car dependency (Boarnet, 2011; Handy, 1996; Jiang et. al., 2017 in Cao et. al., 2019). Accordingly, intervening in the built environment, which is argued to include the man-made or modified structures where we live, work and recreate (US EPA, 2023), is an important way for transport and land-use planning to promote low-carbon travel and development (Yang et. al., 2018).

This built environment is argued able to determine (at least partly):

(i) the number and quality of activities,
(ii) the relative distribution of these activities, and therefore,
(iii) travel distances and the relative transport costs for covering these distances with different transport modes (Zegras, 2010).

As people are supposed to choose their (travel patterns and) vehicle ownership based on maximized utility (Crane, 1996; Maat et. al., 2005, in Jiang et. al., 2017), the more favourable conditions for alternative means of transport, and conversely less favourable conditions for travelling by car that can be created by the built-environment, might be able to initiate a shift from car-based travel towards non-motorized and/or public transport based travel (Cao et. al., 2019). *To illustrate, a built environment that facilitates walking and biking through compact development and reduces associated travel costs might initiate reduced car ownership, as having a car and travelling with it is no longer the highest utility option but has been overtaken by walking or cycling.*

Such compact development (of the built-environment (Ewing and Cervero, 2010; Stevens, 2017 in Elldér et. al., 2022)) is commonly measured in five features, referred to by researchers as the "D-variables" (Stevens, 2017):

(i) Density and diversity places destinations closer together/closer to people's homes, thereby reducing trip length and improving feasibility of alternative travel options.
(ii) Design can make walking and biking more safe and convenient.
(iii) Increased destination accessibility close to home can shorten trip lengths and improve feasibility of alternative travel options.
(iv) Related, decreased distance to transit makes transit more convenient for possible users (Stevens, 2017).

Based on the hypothesis of Zegras (2010) and the argued relatedness of car usage and ownership elaborated on before (Laviolette et. al., 2022; Handy et. al., 2005 in Potoglou and Kanaroglou, 2008), this decreased driving is expected to be associated with decreased car ownership.

2.2 Daily amenity accessibility and car ownership

Considering the "D-variables" indicated above, this study will focus on (*destination) accessibility* in specific. Generally, accessibility has been intended to refer to the possibilities available to reach places where important activities can be undertaken (Linneker and Spence, 1992 in Gutiérrez, 2001), and reflects the ease with which these activities can be reached with certain transportation systems (Morris et. al., 1978, in Gutiérrez, 2001). Accordingly, (destination) accessibility is argued to reflect the distance/proximity to important amenities and public transport (Cervero et. al., 2009 in Fonseca et. al., 2022), with distance to amenities being the most adopted related attribute (Fonseca et. al., 2022).

Relating to this accessibility, residents of areas where key amenities (such as grocery stores) are not (or, no longer) locally available must travel further to reach substitutes (Elldér et. al., 2022). This increased distance might, in turn, reinforce the importance (and ownerships rates) of cars as distances covered, for example, by bike or on foot are limited. *To illustrate, the average distance per trip in the Netherlands for 2021 was 17.08, 4.22 and 2.25 kilometres respectively for car driving, bicycling and walking (Centraal Bureau voor de Statistiek, 2022a).* Accordingly, (destination) accessibility is generally found to be negatively associated with car ownership (e.g., Chen et. al., 2008; Gao et. al., 2008; Kockelman, 1997; Simma and Axhousen, 2003 in Van Acker and Witlox, 2010). Zegras (2010) for example finds that households living further away from the central business district (defined as that part of the city where, among others, important commercial streets and main public buildings are located (Rice, 2009), and thus probably a place where multiple amenities are located), have higher probabilities of owning motorized vehicles.

Corresponding to Zegras (2010), existent literature on built environment – travel relationships is argued to rarely consider local accessibility in detail (van Wee, 2016 in Elldér et. al., 2022). It is however also hypothesized that the presence of (*specific*) neighbourhood amenities, such as restaurants, shops, and schools, enables locally oriented daily living and directly influences travel to several everyday activities (Elldér, 2018; Handy, 2017 in Elldér et. al., 2022). Detailed analysis on the relationship between travel behaviour and local accessibility is argued to be particularly relevant for planning, as the presence of particular amenities in proximity to (and within) residential areas might have triggering effects on travel mode choices (Elldér et. al., 2022).

Matching Elldér et. al. (2022), these everyday/daily (neighbourhood) amenities follow the definition of everyday activities which could be conducted near home, by a large share of the population, on foot or by bicycle (Haugen, 2011 in Elldér et. al., 2022). Exactly which (groups of) amenities this refers to, however, appears to be up for debate: While Witten et. al. (2011) consider eight groups of (*everyday) neighbourhood destinations*, referring to transportation, education, social & cultural, recreation, food and other retail, health and financial services, Elldér et. al. (2022) consider five *everyday activities*, referring to healthcare, shopping, restaurant/café/pub, children and other services.

Following these five everyday activities, Elldér et. al. (2022) explore the role of this *local accessibility* (referring to the number, variety and type of amenities available) in reducing car usage and promoting walking and cycling, for a Sweden (Västra Götaland) based case study. They find that local accessibility in residential neighbourhoods is a central determinant of both mode choice and volume of car usage for everyday activities: as such, favourable local accessibility increases the likelihood of "opting out of" car travel. (While this thus mainly concerns car usage rather than ownership, the argued relationship between these two (e.g., Laviolette et. al., 2022; Handy et. al., 2005 in Potoglou and Kanaroglou, 2008) results in similar effect expectations.)

To gain more understanding on specific daily amenity distance – car ownership relationships, the following section elaborates on current findings regarding *specific* and *common* daily amenity categories (matching categories used by Witten et. al. (2011) and/or Elldér et. al. (2022)), resulting in related hypotheses for this study. Table 7.1 in the Appendix provides a summary of the findings elaborated on.

2.2.1 Specific daily amenity – car ownership relationships

Healthcare accessibility is generally defined as the ease of reaching healthcare facilities and services (by overcoming travel impedances like time, distance, and costs) (Hewko et. al., 2022; Higgs, 2004; Mao and Nekorchuck 2013, in Liu et. al., 2022), measured by, for example, distance (Brabyn and Skelly 2002; Apparicio et. al. 2008, in Liu et. al., 2022). While little research on the relationship between proximity and car ownership is available, Liu et. al. (2022) find in their Chicago Metropolitan Area based study a positive relationship between the percentage of car-free households and (transit – based) healthcare accessibility.

(Hi) This results in the hypothesis that *increased distance towards <u>healthcare</u> is associated with <u>increased</u> car ownership.*

Additionally, Aditjandra et. al. (2012) explore for a UK setting whether changes in neighbourhood characteristics impact travel choice behaviour upon residential relocation. Considering **retail**, they find that when moving to an area with high shopping accessibility (e.g., easy access to district shopping centre or town centre), an individual is more likely to shed a private car. Li and Zhao (2017) find corresponding results in their Beijing based study, where close proximity to a mall is associated with lower car purchase rates (and ownership). Finally, Woldeamanuel et. al. (2009) find that the availability of shops within walking distance significantly decreases the likelihood of car ownership in Germany.

(Hii) This results in the hypothesis that *increased distance towards <u>retail</u> is associated with <u>increased</u> car ownership.*

In the research of Aditjandra et. al. (2012), moving to a more "vibrant social area" is found to be associated with less private car driving (and, following the argued relationship between car usage and ownership elaborated on (Laviolette et. al., 2022; Handy et. al., 2005 in Potoglou and Kanaroglou, 2008), expected less car ownership), providing support for the development of so-called "café style" areas. However, considering these **catering** related amenities, both Li and Zhao (2017) and Woldeamanuel et. al. (2009) do not find a significant relationship between the number of restaurants or availability of bars/cafes within walking distance and car ownership, respectively.

(Hiii) This results in the hypothesis that *increased distance towards <u>catering</u> is associated with <u>increased or unchanged</u> car ownership.*

Considering **alternative mobility,** Zegras (2010) hypothesizes that the relative convenience of different travel mode options influences the utility associated with vehicle ownership. Considering car ownership in a Santiago de Chile based study, households living in areas with poor bus accessibility compared to car accessibility, are accordingly more likely to have car. Reversed, when a household lives within 500 metres of a metro stop, the probability of owning two or more cars decreases. Matching these findings, Woldeamanuel et. al. (2009) find that the availability of a bus/ tram services/U- or S-Bahn within walking distance reduces the probability of car ownership, while Potoglou and Kanaroglou (2008) finally find that a higher number of bus stops within 500 metre of a residence decreases the likelihood of a household to own three or more vehicles.

(Hiv) This results in the hypothesis that *increased distance towards <u>alternative mobility</u> is associated with <u>increased</u> car ownership.*

Considering **children** related facilities, little research is known on the relationship between proximity and car ownership rates. However, McDonald (2008) explores the factors influencing mode choice for both elementary and middle school children in the US. Matching earlier performed studies in the United States, the United Kingdom and Australia (McMillan, 2007; McDonald, 2007b; Schlossberg et. al., 2006 & Black et. al., 2001 & Timperio et. al., 2006 in McDonald et. al., 2008) that indicated distance as critical factor for children's travel, travel time (which they consider to reflect the distance to school) is found to have the strongest effect on the likelihood of walking to school. Here, a 1-minute increase in walk travel time is found to decrease the probability of walking by 0.2%, while a 10% increase in walk travel time decreases the walk mode share with 7.5%. Accordingly, Zwerts and Wets (2006) find in their Flanders based study that for distances over 2 km, children's usage of the bike decreases.

(Hv) Following these results, decreased walking/biking mode share is expected to be associated with increased car mode share and related decreased car ownership rates. Therefore, this results in the hypothesis that *increased distance towards <u>children related facilities</u> is associated with <u>increased</u> car ownership.*

Finally, the existent evidence on the relationship between **leisure activity** (sports and/or culture) proximity and car ownership is again limited. Though, Woldeamanuel et. al. (2009) find varying results: While the availability of a cinema or theatre within walking distance is found to significantly decrease the probability of car ownership, the availability of sport activities does not appear to have significant car ownership effects.

(Hvi) This results in the hypothesis that *increased distance towards <u>leisure activities</u> is associated with <u>increased or unchanged</u> car ownership.*

(Hvii) Following the majority of individual hypothesized *positive* relations between distance towards daily amenities and household car ownership discussed, together with the general elaborations on this relationship made in section 2.2, this additionally results in the hypothesis that *increased distance towards <u>daily amenities in general</u> is associated with <u>increased</u> car ownership.*

2.3 Considerations on the relationship form

Besides the "general" direction of the relationship between the distance to specific daily amenities and household car ownership just discussed, several considerations on the (non-linear) form of this relationship are assessed, referring to (i) diminishing sensitivity and (ii) a possible interaction effect with the accessibility of alternative transport options.

2.3.1 Diminishing sensitivity

Being one of the three fundamental features of Prospect Theory, diminishing sensitivity implies that marginal values of gains and/or losses decrease with higher attribute levels (Stathopoulos and Hess, 2012), or that sensitivity for increases in gains and/or losses diminishes (Van de Kaa, 2010). Considering wealth, the difference between 950 and 1,000 euros is subjectively considered smaller than the difference between 50 and 100 euros (Cole, 2018).

Found applicable in travel-related settings (De Blaeij and Van Vuuren 2003; De Borger and Fosgerau 2008 in Van de Kaa, 2010), this might also suggest that decreases or increases in travel distance to daily amenities is subject to diminishing sensitivity/decreasing returns. *That is, a decrease from 10 to 9 kilometres might be considered "less" compared to a decrease from 2 to 1 kilometre, and therefore might also be associated with smaller effects on travel behaviour in terms of car ownership*. Accordingly, Zegras (2010) finds decreasing returns/diminishing sensitivity for the relationship between central business district distance and the probability of owning motorized vehicles: while the general relationship is positive (elaborated on in section 2.2), a negative squared coefficient implies that when distance continuously increases, a negative effect on car ownership appears.

(Hviii) This results in the hypothesis that *the relationship between distance towards daily amenities and car ownership is characterized by <u>diminishing sensitivity (/decreasing returns).</u>*

2.3.2 Mobility alternative interaction

In line with the aim of this research, CROW commissioned a Dutch study into the influence of several factors on people's decision to not buy or dispose of a car when moving to an inner-city area (Klimaatweb, 2021). Here, 70% of the respondents indicated that they would be prepared to do so *if* the right circumstances exist: That is, when high-quality alternatives are available (public transport, bike, and shared transport) and shared transport leads to cost savings (Klimaatweb, 2021).

When interpreted freely, this former factor might indicate that people are willing to give up on a car for shortened distances to amenities (assuming to be the case in these inner-city areas), *if* there are suitable alternatives. *Reasoning, shorter distances might be nice, but of trivial effect on car ownership when there is no alternative to the car for covering these (albeit shorter) distances.*

(Hix) When considering the earlier hypothesized positive relationships between distance towards daily amenities and car ownership (section 2.2.1), this results in the hypothesis that *there is a negative interaction effect between distance towards daily amenities and distance towards alternative mobility on car ownership.* That is, with smaller distances to mobility alternatives, a decreased distance to daily amenities has larger car ownership reduction effects (because the alternative is well accessible) than with larger distances to mobility alternatives (because the alternative is less accessible).

2.4 Non-accessibility determinants of car ownership

As argued in section 2.0, travel distance might be *one of many factors* influencing car ownership. Therefore, several other (non-distance related) factors are expected able to influence car ownership. A summary of the findings elaborated on below is provided in Table 7.2 in the Appendix.

2.4.1 Socio-economic and demographic factors

Considering **age**, Van Acker and Witlox (2010) pose that car ownership rates are lower among older people (aged above 65 years). Accordingly, Nolan (2010) finds in an Irish longitudinal 1995-2001 based study that households with a household reference person (HRP) aged over 35 years are significantly more likely to own a car compared to households with a HRP aged 16-34 years, while this positive effect is smaller for HRP aged above 65 years. Oakil et. al. (2016) additionally find in their Netherlands based study that, as in many developed countries, car ownership among young adults is decreasing.

While there is no existent (general) literature found on the relationship of (i) **gender** and (ii) **migration background** with car ownership, available literature concerning car usage elaborated on below and the earlier argued positive relationship between car usage and ownership (e.g., Laviolette et. al. (2022); Handy et. al. (2005) in Potoglou and Kanaroglou (2008)), results in the expectation that there will be a similar relationship (in terms of effect direction) with ownership:

(i) Van Acker and Witlox (2010) argue women to be more inclined to (a) commute by public transport, on foot or by bike, and (b) travel to shops within biking or walking distance from home (the latter e.g referring to Schwanen et. al., 2002). Accordingly, Witte et. al. (2022) argue that there are almost twice as many cars registered in the name of a man (compared to women).

(ii) Mattioli and Scheiner (2022) argue (based on a range of existing research) that people with a migration background tend to drive the car less.

Concerning **income and employment,** income is argued to provide a household with the financial means to maintain and own a car (Roorda et. al., 2000 in Potoglou and Kanaroglou (2008)), while high-income might also be associated with *more expensive cars* rather than a *greater number* (Prevedouros and Schofer, 1992 in Potoglou and Kanaroglou (2008)). Zegras (2010) concludes that income serves as the most important (positive) driver of household vehicle ownership, while Li and Zhao (2017) and Aditjandra et. al. (2012) respectively find that income is positively associated with car ownership likelihood (at present and in the future) and car ownership. Related, Nolan (2010) finds a positive association between the household reference person (HRP) being employed and household car ownership probabilities. In many cases, workers receive financial support from the employer (e.g., free parking at work and mileage allowance), reducing the costs for a car and increasing car ownership (Witte et. al., 2022).

Finally, Van Acker and Witlox (2010) argue that intra-household decisions on activities of **multiple household members** increases the need to own multiple cars for larger households, while Zegras (2010) also considers the possibility that as household size increases, the attractiveness of vehicle ownership decreases as more expenditures are required to feed, clothe etc. all household members. In accordance with Van Acker and Witlox (2010), both Li and Zhao (2017) and Aditjandra et. al. (2012) find that larger household sizes are associated with increased (likelihood of) car ownership, respectively. Similarly, Nolan (2010) finds that both the presence of children aged under 12 years, and an increased number of adults in the household is associated with increased household car ownership probabilities. Ultimately, household composition was found to be the most important factor (together with urbanisation level) determining car ownership among young adults, with families being more car dependent than couples and singles because of more complex daily travel needs (Oakil et. al., 2016).

2.4.2 Other built-environment related factors

Besides socio-economic and demographic factors, other (non-accessibility) built environment related factors might also influence car ownership levels. Aditjandra et. al. (2012) for example find (in their earlier discussed research) that *safety considerations* of the residential environment (e.g. safety within the neighbourhood for walking, good street lightning) increase car ownership (while this might also reflect the "suburbaness" of neighbourhoods). Additionally, Zegras (2010) finds that *living in an apartment* decreased the likelihood of owning motorized vehicles.

In Figure 2.1 below, the conceptual model of all discussed factors capable of influencing household car ownership is graphically presented. For the distance variables of interest also the hypothesized direction of the effect is shown.

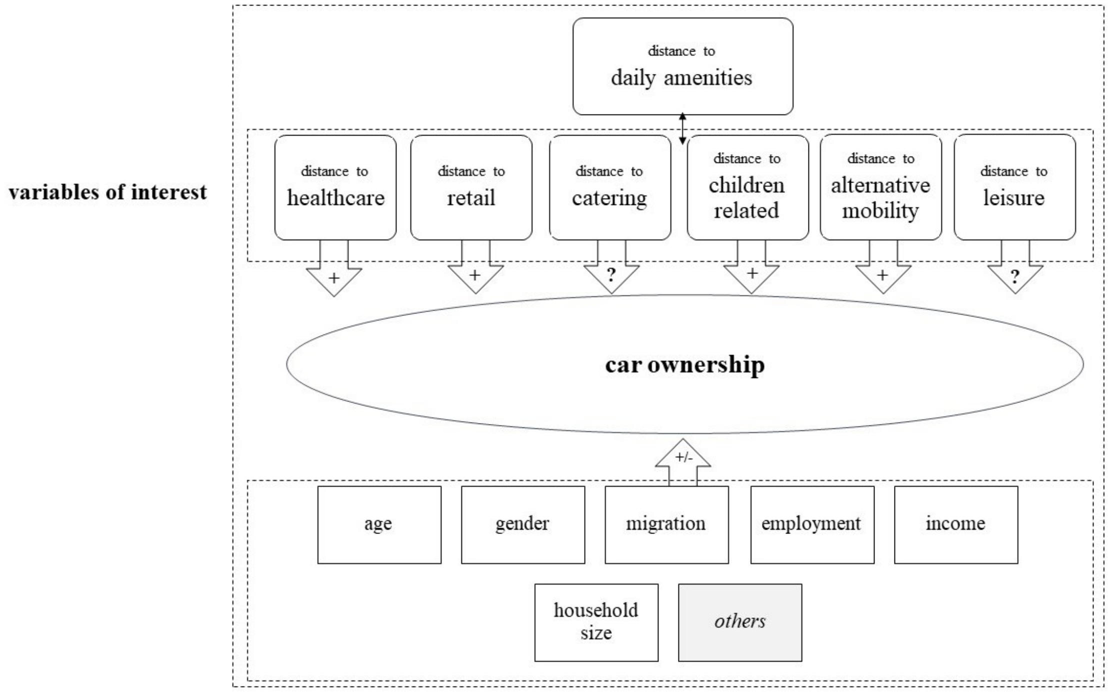


Figure 2.1 Conceptual model
Notes: "Others" refers to other factors, not included in the model able to influence car ownership (e.g. relating to factors elaborated on in section 2.0 and 2.4.2). However, these factors might be captured by the fixed effects added in the panel model specifications (as indicated in section 4.3.1).

3. Data

As argued, this study aims to answer *how accessibility for daily amenities (in terms of distance) influences (household) car ownership in Dutch urban neighbourhoods.* To do so, hypotheses on the relationship between distance towards various daily amenities and car ownership have been determined in section 2.2.1 based on existent findings. To test/assess these hypotheses, the following section discusses the characteristics of the data used. Therefore, first general elaborations on the data source will be made, followed by sample selection considerations and possible data modifications.

3.1 General data elaboration

All data used relates to open data from *Centraal Bureau voor de Statistiek* (from now on, CBS). Based on the need for reliable and independent information to understand social issues, CBS, as the number one statistical office in the Netherlands, supplies data and reliable statistical information (Centraal Bureau voor de Statistiek, n.d.-e).

From CBS, both so-called *key figures neighbourhoods and districts* and *proximity statistics* are used and merged for several years. These indicate general key figures (available for the period 2004-2022) and figures regarding distance to and density of amenities (available for the period 2006-2019) respectively for all Dutch municipalities, districts and neighbourhoods (Centraal Bureau voor de Statistiek, 2020; n.d.-c;n.d.-g). While for the cross-sectional analysis the most recent year of full data availability is used (2019), for the panel analysis an interval of the most recent 10 years is used (2009, 2014 and 2019) (further elaborated on in section 4.3.1).

3.2 Analysis level and sample selection

Referring back to the research question, the analysis is at *urban neighbourhood level*:

(i) *Neighbourhoods* are the most disaggregated regional measurement available (and thus the lowest probability of missed underlying processes), being part of a municipality and often also of a district (Centraal Bureau voor de Statistiek, n.d.-a).

(ii) For this study, *"urban"* neighbourhoods refer to neighbourhoods by CBS classified as very highly to moderately urban (that is, having an average environmental address density (per km2) larger than 1,000 (Centraal Bureau voor de Statistiek, n.d.-d)).

Here, *urban* neighbourhoods expectantly refer to the "type of neighbourhood" in which shortened distance to daily amenities is able to replace cars with other modes of transportation (e.g. walking, cycling or public transportation). *Intuitively, in rural areas the distance to these amenities will be considerably larger, making a possible change in behaviour resulting from a change in distance less likely (e.g., following the hypothesis on* *diminishing sensitivity in section 2.3.1).* Accordingly, in the “raw” (that is, no modifications or filters applied) dataset retrieved from CBS, the average distance to daily amenities researched (measured as the overarching umbrella factor elaborated on in section 4.2.2) is 2.2 and 5.6 kilometres for neighbourhoods classified as urban and rural respectively, a difference which is statistically significant at the 1% significance level.

Moreover, a focus on urban neighbourhoods matches the aim of several Dutch cities (probably containing urban neighbourhoods) to transition away from cars elaborated on before (Gemeente Rotterdam, n.d.; Gemeente Utrecht, 2022; Gemeente Amsterdam, n.d.; Gemeente Leiden, n.d.; Folkers, 2021).

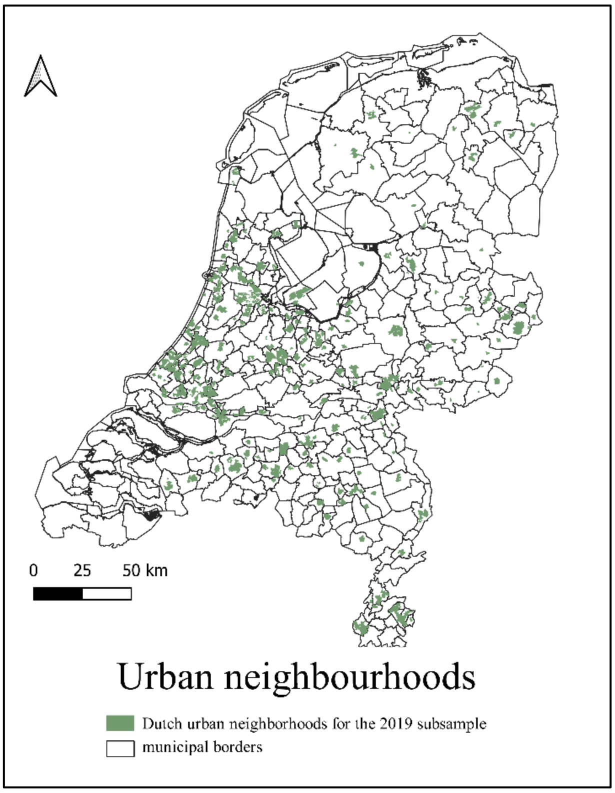


Figure 3.1 Map of the geographical distribution of “urban” neighbourhoods, 2019
Notes: These refer to the urban neighbourhoods used in the cross-sectional analysis for 2019 (that is, after outlier application etc.) Basemap: Centraal Bureau voor de Statistiek (n.d.-b)

As the degree of urbanity for a neighbourhood can change over the years, the final data selection only includes neighbourhoods that are classified as “urban” throughout the whole observation period. While these neighbourhoods mainly appear to be concentrated in the west of the Netherlands (See Figure 3.1 above), they are present in every Dutch region (and are therefore considered to be fairly representative for the Netherlands as a whole).

In addition, neighbourhoods for which CBS indicates that the figures cannot be compared one-to-one with observations of this neighbourhood in any previous year are fully excluded from the analysis.

Therefore, only neighbourhoods that are *considered comparable* over the entire period available for that neighbourhood are included. It must however be noted that this concerns "considered comparable" because these refer to "last year indications": if an observation from 2019 is comparable to that of 2018, but not to that of 2014, no indication is available, and it will therefore likely not be excluded from the analysis.

Finally, an 'extreme outlier threshold' is determined for all variables used in the analysis (documented in Table 7.3 of the Appendix). Values exceeding this threshold are excluded from further analysis. Note that because none of these outlier values refer to "infeasible" values, rather wide "okay" ranges are used and only true "extreme" values (which might have a considerable impact on the results) are excluded. Here, outliers appear to be concentrated in certain neighbourhoods. That is, while the first outlier filter applied results in the exclusion of many observations (942), this number is much lower for the subsequent filters (ranging between 0 and 142).

3.2.1 Data modifications

Considering specific data modifications, for the control variables (elaborated on in section 4.2.3) several adjustments have been made. Unlike the other observation years used (2009 and 2014), 2019 documents *absolute* rather than *relative* demographic figures. For consistency in specification between the years, these have been converted to relative terms (and, matching the other observation years used, rounded to whole numbers). In addition, for all years, the absolute number of men and women are, for consistency with the other variables, also converted into relative terms and rounded accordingly.

4. Methodology

To test/assess the hypotheses determined with the data elaborated on, the following section explains the analysis techniques used for the cross-sectional and panel models. Table 4.1 below summarizes all models employed. For these models, first regression equations and associated interpretation for the found coefficients of the main distance variables of interest will be described. Thereafter, individual elements of the regression setup and the variables within will be elaborated on.

Table 4.1 Summary of all model specifications employed

Model specification		**Model #**				
		1	2	2b	2c	3
Amenity level	Umbrella factor	x				
	Factor		x	x	x	
	Individual					x
Considerations	Diminishing sensitivity			x		
	Alternative mobility interaction				x	

Notes: All specifications additionally incur the same set of neighbourhood control variables, and all panel models incur municipal and time fixed effects.

4.1 Mathematical regression setup

To answer the research question *how accessibility for daily amenities (in terms of distance) influences (household) car ownership in Dutch urban neighbourhoods*, the relationship between distance to daily amenities (either as (overarching umbrella) factor or distinct/individual type) and household car ownership will be estimated (based on the conceptual framework in section 2).

- For the cross-sectional analysis, the research question refers to how the proximity of amenities influences car ownership, *comparing urban neighbourhoods*. That is, do neighbourhoods with smaller distances to the nearest amenity have lower car ownership rates compared to neighbourhoods with larger distances, and which amenities are important in this relationship. In this *between* analysis, cross-sectional data on the most recent year available (2019) will be used in a level-level Ordinary Least Squares regression with standard robust errors (error considerations elaborated on in section 4.3.2).

- For the panel analysis, the research question refers to how *increasing* proximity of amenities influences car ownership, *within urban neighbourhoods*. That is, do neighbourhoods where distances decrease experience car ownership reductions and which amenities are important in this relationship. In this *within* analysis, panel data between 2009 and 2019 (in interval) will be used in a level-level Fixed Effects regression with clustered standard errors (elaborated on in section 4.3.1 and 4.3.2).

Both result in the ***basic regression equation (1)*** below, where the number of cars per household is estimated from the distance in kilometres towards

(1) Daily amenities in general
(g *indicates the "umbrella" factor of daily amenities in general* in Model 1)

(2) Several daily amenity groups/factors
(*f indicates the range of amenity factors* in Model 2), or

(3) Several individual daily amenities
(i *indicates the range of individual amenities* in Model 3), or

which are indicated by the variable $distance\ to\ amenity_{i/f/g}$ (see Table 4.1 above for summarized model specification and Table 4.3 below for factor specifications). Additionally, several neighbourhood socio-economic and demographic factors (k indicates the range of these variables) indicated by $neighbourhood\ controls_k$ are added (elaborated on in section 4.2.3), and supplemented with both municipality and time fixed effects for the panel analysis only (indicated by $FE_{municipality} + FE_{time}$) (elaborated on in section 4.3.1).

$$number\ of\ cars\ per\ household = \beta_1 * distance\ to\ amenity_{i/f/g} + \beta_2 * neighbourhood\ controls_k + (FE_{municipality} + FE_{time}) + u$$

Basic regression equation (1)
Notes: g indicates the umbrella factor of daily amenities in general (Model 1), f indicates the range of amenity groups/factors (Model 2), i indicates the range of individual amenities (Model 3), k indicates the range of neighbourhood control variables, fixed effects in brackets are only used for the panel data based analysis.

Estimated coefficients of the *distance to amenity* variables of interest should be interpreted as followed: *On average, a one-kilometre increase in the distance to the nearest [amenity$_{i/f/g}$] is associated with a β1 (hypothesized) increase in the number of cars per household.*

4.1.1 Considerations on the relationship

As argued (see section 2.3), several considerations on the found relationship are explored. In the equations described below, subscripts have the same meaning (and *fixed effects* are only relevant for the panel data analysis). To accommodate interpretation but also allow for deviation within the found relationship for different types of amenities, both considerations are added separately for the amenity factors (Model 2) only.

(2b) Considering *diminishing sensitivity/decreasing returns* (elaborated on in section 2.3.1) and to test for a non-linear distance relationship, a quadratic term for the amenity factors is added. For both the cross-sectional and panel analysis, this refers to Model 2b, which corresponds to the ***diminishing sensitivity regression equation (2)*** below.

$$number\ of\ cars\ per\ household = \beta_1 * distance\ to\ amenity_f + \beta_2 * distance\ to\ amenity_f^2$$

$$+\beta_3 * neighbourhood\ controls_k + (FE_{municipality} + FE_{time}) + u$$

Diminishing sensitivity regression equation (2)
Notes: f indicates the range of amenity groups/factors (Model 2), k indicates the range of neighbourhood control variables, fixed effects in brackets are only used for the panel data-based analysis.

(2c) Considering interaction with accessibility of alternative mobility options (elaborated on in section 2.3.2), an interaction term between the *alternative mobility factor* and all other *daily amenity factors* is added. Naturally, such a interaction effect is not included for the alternative mobility factor (as this is equal to the quadratic term). For both the cross-sectional and panel analysis, this refers to Model 2c, which corresponds to the ***interaction regression equation (3)*** below.

$$number\ of\ cars\ per\ household$$
$$= \beta_1 * distance\ to\ amenity_f + \beta_2 * (distance\ to\ amenity_f$$
$$* distance\ to\ alternative\ mobility) + \beta_3 * neighbourhood\ controls_k$$
$$+ (FE_{municipality} + FE_{time}) + u$$

Interaction regression equation (3)
Notes: f indicates the range of amenity groups/factors (Model 2), k indicates the range of neighbourhood control variables, fixed effects in brackets are only used for the panel data-based analysis.

To assess the sensitivity of these results, additionally, a model with both form considerations will be employed. This refers to model 2b/c (including both quadratic and interaction terms).

4.2 Specification of the variables

4.2.1 Dependent variable

For all models, the dependent variable of interest refers to the (*average) number of passenger cars per private household* (on January 1st, per neighbourhood and only documented for a minimum of 50 households per neighbourhood, and with a maximum value of 2.5). As these passenger cars are regionally classified based on license plate registration, it must be noted that cars registered at rental or leasing companies could possibly distort the figures (Centraal Bureau voor de Statistiek, 2022b).

Table 4.2 below illustrates the descriptive statistics for the whole period, and the individual years in specific for the data sample used. The average number of cars per household appears to have increased over time (difference between 2019 and 2009 statistically significant at the 1% significance level). Figure 4.1 below moreover illustrates the distribution of this variable, showing that (i) the removal of outliers (as discussed in section 3.2) was successful, and (ii) the distribution resembles a normal distribution.

Table 4.2 Descriptive statistics number of passenger cars per household, for urban neighbourhoods 2009-2019

Number of cars per household	N	Mean	SD	Min	Max
2019	3,876	0.919	0.283	0	2.0
2014	3,451	0.919	0.265	0.1	2.0
2009	3,183	0.896	0.247	0.1	2.0
2009 - 2019	10,510	0.912	0.267	0	2.0

Notes: Descriptive statistics are retrieved after *applying outlier filters/sample selection.*

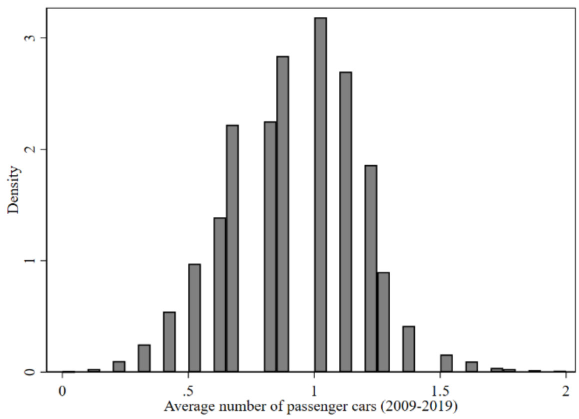


Figure 4.1 Distribution number of passenger cars per household, for urban neighbourhoods 2009-2019

The usage of an *average per household* measure is expected to account for the size and population density of the neighbourhood (an (i) absolute/ (ii) per area measure might results in higher car ownership levels in (i) neighbourhoods with more residents/ (ii) more densely populated neighbourhoods). Although the per household measurement is probably still subject to the number of people *within* this household (as elaborated on in section 2.4.1), by additionally controlling for the average household size (see section 4.2.3), an attempt is made to account for this.

4.2.2 Independent variables of interest

The independent variables of interest refer to *the average distance to the nearest amenity.* This distance is calculated as the average travel distance (in kilometres) for residents within a neighbourhood from their home address to the nearest available amenity, over paved roads used by cars (thus, excluding pedestrian and bicycle paths, but taking into account ferry transfers, grade-separated intersections and one-way traffic on national and provincial roads) (Centraal Bureau voor de Statistiek, n.d.-f).

The focus is here, matching the previously discussed study by Elldér et. al. (2022), on everyday activities that can be conducted near one's home by a large share of the population, on foot or by bicycle (Haugen, 2011 in Elldér et. al., 2022), in other words: *daily amenities*. While the proximity statistics retrieved provide distances for a range of amenities, by CBS defined as a location consistent with usage in everyday life, that can be visited by individuals (Centraal Bureau voor de Statistiek, n.d.-g) (thus, roughly matching the earlier indicated definition by Haugen, 2011 in Elldér et. al., 2022)), only those who actually meet this classification and match findings on specific and common daily amenity distance – car ownership relationships (and related determined hypotheses in section 2.2.1) are considered. Therefore, for example*, hotel, sauna, tanning bed, attraction, ice rink* and *fire station* (the latter not really considered to be an amenity) are not included in the analysis.

The usage of proximity (distance to nearest) rather than variety (e.g., number of amenities within x kilometres) is moreover in line with this aimed contribution regarding the discussion on the development of "compact cities".

Table 4.3 Distinct groups of amenities researched and sub-amenities that make up these groups

(1)	(2)	(3)
Umbrella	**Amenity factor**	**Sub-amenities**
General amenity accessibility	Healthcare	General practice, pharmacy, hospital
	Retail	Large supermarket, other shop for daily groceries, department store
	Catering	Cafes, cafeteria, restaurant
	Children related facilities	Day-care, school-care, primary education, secondary education
	Alternative mobility	Train station, important transfer station
	Leisure	Library, swimming pool, performing arts, cinema

Notes: These groups and sub-amenities are additionally used for the factor analysis. That is, the umbrella factor of column 1 consists of the amenity factors in column 2, and the amenity factors of column 2 consist of the sub-amenities in column 3.

As argued, the relationship with car ownership will be estimated for amenity categories as a group (Model 2, in column 2 of Table 4.3 above), and the various sub-amenities (Model 3, in column 3 of Table 4.3 above). Concerning the former, a so-called factor analysis will be performed in which, for example, the factor *healthcare* reflects the average distance towards *healthcare* amenities for a certain neighbourhood, referring to the average distance to *general practice, pharmacy,* and *hospital.* This same rationale applies to all other amenity groups. Additionally, one *umbrella* factor, based on the average for all 6 groups (Model 1, in column 1 of Table 4.3 above) is added for the determination of a "general" effect.

By estimating the relationship between daily amenity distance and household car ownership for multiple levels of amenity aggregation, the general relationship can be estimated, but also the detailed relationships of importance within, matching the aspired contribution for built-environment planning. That is, the multi-level analysis makes it possible

(1) To determine the *general* relationship between daily amenity distance and household car ownership (that is, test general ***hypothesis (Hvii)***)
(2) To determine the overall relationship between *different groups* of daily amenity distances and household car ownership (that is, test ***hypothesis (Hi-Hvi)***), and, therefore
   - To identify the amenity groups of importance within the *general* (1) relationship
(3) To determine the relationship between *specific types of* daily amenity distances and household car ownership, and, therefore
   - To identify the individual amenities of importance within the *general* (1) and *group* (2) relationships

Table 7.4 in the Appendix illustrates the definitions (if there is any ambiguity) and descriptive statistics. It appears that, on average, the distance to *cafeterias* (for the panel sample, on average 0.54 kilometres) and *day-care* (for the cross-sectional sample, on average 0.50 kilometres) are smallest, while *important transfer stations* refer to the amenities located at the largest distance (on average, 8.07 and 8.93 kilometres for the cross-sectional and panel sample respectively) (average distances are fairly similar for the cross-sectional and panel sample). Figure 4.2 below additionally illustrates the distribution for the *retail* factor as example, showing that the removal of outliers (as discussed in section 3.2) was successful.

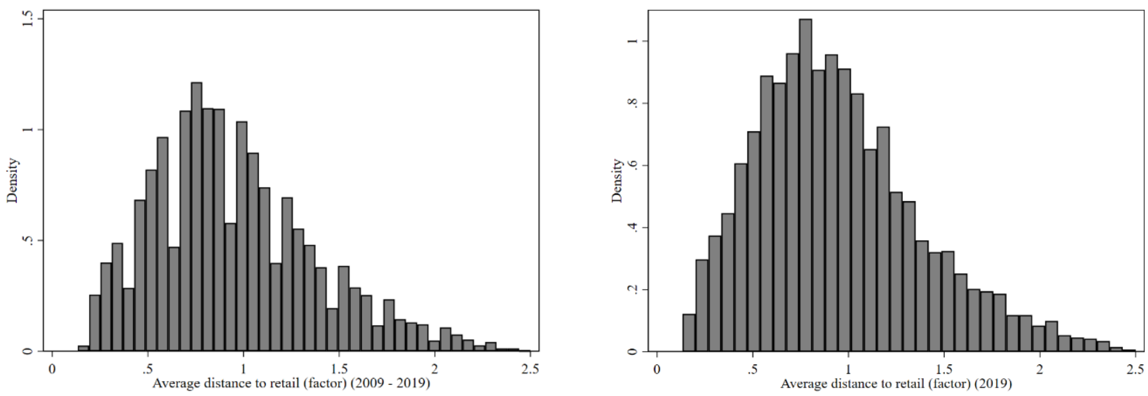


Figure 4.2 Distribution retail (factor)

Correlations between these independent variables (for the whole/panel sample) indicate that for the individual distances, the *distance to other shop for daily groceries* is considerably correlated with both the *distance to large supermarket* (0.71) and the *distance to cafeteria* (0.75), leading to a sensitivity analysis on its exclusion.

4.2.3 Control variables

As indicated in section 2.4.1, a range of socio-economic and demographic factors can considered to be determinants of household car ownership. As they can also be correlated with distance to daily amenities, they can potentially introduce bias to the estimates. *As an illustration (and not necessarily true), besides age having an effect on car ownership (section 2.4.1) it might also be that young people are more likely to live in areas with more amenities in proximity (while older people prefer peace and quietness).* Therefore, several control variables will be included in both the cross-sectional and panel analysis, aiming to account for this bias. The inclusion of sociodemographic controls is moreover argued able to partly prevent bias resulting from residential self-selection (Brownstone and Golob, 2009 in Elldér et. al., 2022), further elaborated on in section 6.1.

However, correlations between variables available indicate that marital status and household specification (the latter being e.g., with/without children) provide fairly large correlations with on literature basis preferred other control variables (e.g., age groups and household size respectively) and are therefore excluded from the analysis. In addition, there are some high correlations within preferred control variable groups (gender and migration background), which result in a sub-selection being used (of men only and aggregated migration). Considering the different age groups, children (which have a high correlation (0.81) with household size) and students (together, ranging between the age of 0 and 25 years) are excluded from the analysis as (i) they (at least partly) cannot/are not allowed to own a car, (ii) they are implicitly accounted for through their relationship with the share of other age groups, and (iii) their influence on the number of cars within the household is expected to be included in the household size variable.

Moreover, a trade-off regarding the inclusion of "bad controls" leads to sensitivity analysis on the *population density* of a neighbourhood: As population density is found to have a negative effect on car ownership levels (Hanly and Dargay, 2000), car ownership rates are expected to be lower in these areas.

- On the one hand, one could argue that this is part of the amenity proximity effect and population density is therefore a bad control. That is, *because* amenities are in close proximity, and this is desirable *("amenities are nice"),* a lot of people locate here, increasing population density and (further) reducing car ownership rates *(for example and not necessarily true, because of congestion)*. (In this case, decreased amenity distance reduces car ownership through the distance effect elaborated on *and* its influence on population density).
- On the other hand, one could argue that this a *correlation* rather than part of the amenity proximity effect. Then, the exclusion of a density variable can introduce bias in the estimated distance effects.

Because the aim of this study is to estimate the *total effect* of amenity proximity on household car ownership, models without population density are overall preferred.

Ultimately, the model incorporates measures on *age*, *gender* and *ethnic background* distribution, *income* specifics (income and number of income recipients as proxy for being employed) and *household* size, matching the "other determinants of car ownership" elaborated on in section 2.4.1. Descriptive statistics and (if needed) definitions of the final selection of control variables are documented in Table 7.5 of the Appendix. Also here, the removal of outliers was successful.

4.3 Analysis technique

As argued, a cross sectional and panel level-level-regression will be performed, following the regression equations documented in section 4.1. The following section elaborates on the analysis technique used and highlights several important individual elements within these equations, referring to the usage of fixed effects and considerations on the appropriate estimation of standard errors.

Given the beforementioned immediate adaptation of travel behaviour to urban form (Donaghy et. al., 2004), the inclusion of lags or leads is moreover considered inappropriate.

4.3.1 Fixed effects (panel regression)

While the inclusion of several demographic and socio-economic characteristics of the neighbourhoods allows for the control of multiple potential bias causing factors, there may still be unobservable factors biasing the estimates. Exploiting only individual *within* variation to estimate coefficients through usage of individual fixed effects in a panel regression analysis allows for the control of *all stable* individual characteristics, measured or not (Allison, 2009).

The usage of fixed effects requires, besides multiple directly comparable measurements of the dependent variable (which, considering the usage of panel data is expected to be the case), that independent variables of interest vary across measurements for a considerable portion of the sample (Allison, 2009). To promote this required variation in the main distance variables of interest (*distance to e.g. supermarket probably does not differ every year, but more likely every five years*), the 10-year data will be used in 5-year intervals (2009-2014-2019). However, still, the variation in distances appears to be low: as an illustration, for 2878 and 3062 of the between-wave differences in distance to a *general practice* or *large supermarket*, this difference is 0 (which is equal to 52 and 55 percent of the change observations). When applying fixed effects at the neighbourhood level, these observations will be absorbed by the fixed effects, considerably limiting the amount of variation left in the model. Therefore, to further promote variation, fixed effects will be applied at the higher municipality level (because not all neighbourhoods could be matched to a district, using fixed effects at this level was deemed undesirable).

That is, for this analysis, using municipality fixed effects allows for the control of characteristics that are constant over time, but differ between municipalities (derived from Hanck et. al., 2023). While a test for indication of the appropriateness of fixed effects (e.g., Hausman test) does not provide sensible results for all models/ is not available for models with clustered standard errors (error considerations elaborated on in section 4.3.2), their ability to allow for the elimination of this bias results in a preference for their use. These municipal fixed effects ($FE_{municipality}$) might be able to (partly) capture:

(i) some of the *mobility preferences* (elaborated on in section 2) within the municipality, assuming that these stay constant over time,

(ii) *overall* quality, quantity, and safety of different infrastructures (the latter referring to the in section 2.4.2 mentioned considerations by Aditjandra et. al. (2012)),

(iii) location within the country (e.g., relative to key locations), and

(iv) housing type distribution (referring to the in section 2.4.2 mentioned considerations on apartment living by Zegras (2010)).

Although the usage of interval data over 10 years is thus expected to accommodate the amount of variation, it however also limits the amount of stable characteristics that can be controlled for by these fixed effects (*as limited factors are expected to stay constant over 5 years, compared to a, for example, 2 year period*). Therefore, the municipal fixed effects are supplemented with *time fixed effects* (FE_{time}), able to control for factors that are constant across the municipalities but change over time (derived from Hanck et. al., 2023). For this analysis, this might refer to

(i) the overall change in attitudes towards car ownership (as data inspections in section 4.2.1 show, average car ownership per household increased over the years),

(ii) but also, national price- (e.g. for petrol, but also cars themselves or maintenance) and tax-changes.

Combined, the fixed effects thus allow for the elimination of bias from (a) unobservables that differ across municipalities but are fixed over time (*municipal fixed effects*), and (b) unobservables that differ over time but are the same for all municipalities (*time fixed effects*) (derived from Hanck et. al., 2023). As a result, only unobservables (that is, factors not included in the additional control variables) that change over time *and* differ across municipalities are still able to introduce bias in the model, but this influence is considered limited.

4.3.2 Error distribution

Heteroskedasticity: When the variance of the conditional distribution of the error term, given the independent variable(s), is non-constant, the error term is considered to be *heteroskedastic* (Hanck et. al., 2023). If so, caution is needed when making conclusions regarding the significance of coefficients (Hanck et. al., 2023), and the usage of *robust* standard errors may be preferred (Zach, 2020).

The visualization of the error terms for Model 2 in Figure 4.3 (cross) and 4.4 (panel) below, indicates that when the distance to healthcare increases, the variation in the error terms decreases, hinting towards heteroskedasticity (similar conclusions for other non-shown plots). This conclusion is reinforced by the

Breusch-Pagan test: Here, (as documented in Table 4.4 below), for all five cross-sectional models the null hypothesis that there is constant variance can be rejected at the 1% significance level and robust standard errors are preferred.

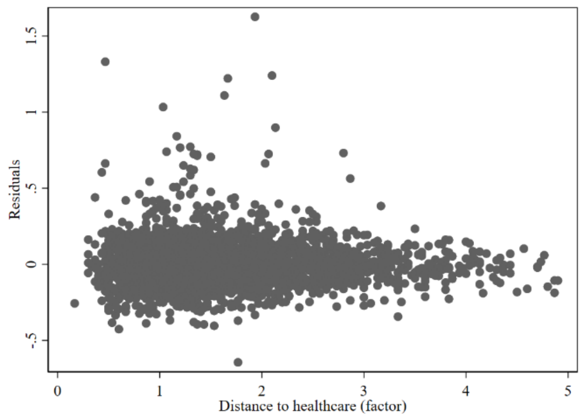


Figure 4.3 Plot of residuals versus distance towards healthcare, for the preferred cross-sectional Model 2

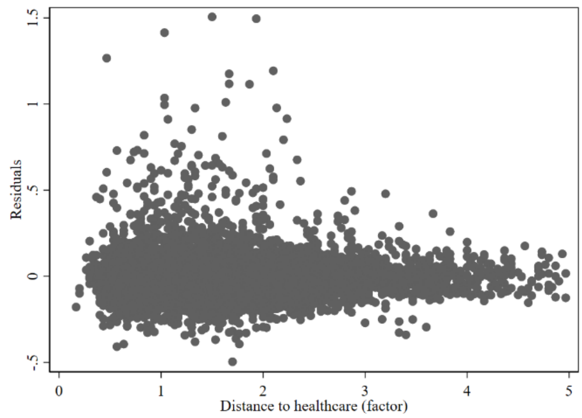


Figure 4.4 Plot of residuals versus distance towards healthcare, for the preferred panel Model 2

Table 4.4 Cross sectional Breusch-Pagan test results

	Cross-sectional				
	(1)	(2)	(3)	(2b)	(2c)
Chi^2	146.45	95.16	80.68	83.68	93.94
p-value	0.000	0.000	0.000	0.000	0.000
Controls	*YES*	*YES*	*YES*	*YES*	*YES*
Outlier filters	*YES*	*YES*	*YES*	*YES*	*YES*

Notes: A p-value of 0.000 is in all cases associated with a rejection of the null hypothesis of constant variance.

Autocorrelation: For panel data, the presence of *serial autocorrelation* (or, *serial correlation)* (in which time series observations are correlated (Hanck et. al., 2023)) should also be considered. Therefore, a *Wooldrigde* test for autocorrelation in panel-based models (Wiggins & Poi, n.d.) is performed and results are documented in Table 4.5 below.

Table 4.5 Panel Wooldridge test results

	Panel				
	(1)	(2)	(3)	(2b)	(2c)
Chi^2	7.09	6.98	328.01	7.06	6.95
p-value	0.01	0.01	0.00	0.01	0.01
Controls	*YES*	*YES*	*YES*	*YES*	*YES*
Individual/Time FE	*NO*	*NO*	*NO*	*NO*	*NO*
Outlier filters	*YES*	*YES*	*YES*	*YES*	*YES*

Notes: Wooldridge test does not allow for the inclusion of fixed effects. All p-values are associated with a rejection of the null hypothesis of no first-order autocorrelation.

Here, the null hypothesis that there is no first-order autocorrelation can be rejected at a 5% significance level for all panel models, hinting towards the presence of autocorrelation. Therefore, errors in different years, for a given neighbourhood might be correlated and "clustered errors" may be preferred (derived from Cameron and Miller, 2015). Additionally, there may be *spatial autocorrelation* (in which there is a relationship between nearby spatial units (Getis, 2009)). Therefore, errors for neighbourhoods in the same region might be correlated, and again "clustered errors" may be preferred (derived from Cameron and Miller, 2015).

Here, observations can be grouped into clusters for which model errors are correlated *within* clusters, but uncorrelated *across* clusters (Cameron and Miller, 2015). While it is not always clear what level of clusters should be used (given the trade-off in which larger clusters have more variability but less bias) and there might even be multiple ways to cluster, Cameron and Miller (2015) argue that the consensus is to avoid bias and use larger and more aggregated clusters where possible (and up to the point where these is worry on having too few clusters). Taking into account this advice and their general recommendation of using clusters at a higher level (e.g. rather state than county level for individuals within counties, within states), both considerations on *spatial* and *serial autocorrelation*, and matching the cluster level to the level of fixed effects (the latter are argued able to partially control for the within-cluster error-correlation, but generally believed unable to control for all of it (let alone heteroskedasticity)), errors are clustered at the *municipal level* (which results in 231 clusters). By doing so, (errors of) observations of

(i) different neighbourhoods, referring to *spatial autocorrelation*,
(ii) in different years, referring to *serial autocorrelation,*

within a municipality can be correlated.

5. Model Results

Using the models elaborated on, the following sections highlights the results regarding the main question of *how the accessibility of daily amenities (in terms of distance) influences (household) car ownership in urban neighbourhoods*. Therefore, first results regarding the basic proximity effect of (overarching) factor and distinct types of amenities will be assessed, followed by non-linear considerations on these relationships. Finally, sensitivities to different model specifications will be evaluated and possible limitations will be determined. While this section highlights important results, Table 7.7, Table 7.6, and Table 7.8 and 7.9 in the Appendix provide full regression results for the preferred models, model establishments and sensitivity analyses, respectively.

The effects found for the added neighbourhood control variables mostly (and statistically significantly) correspond to the literature discussed in section 2.4.1 and is therefore not further discussed. (Only the number of income recipients is surprisingly negatively related to household car ownership, *which may indicate that this variable (partly) reflects the number of people rather than the number of people* employed. In addition, a higher proportion of older people is, inconsistent with the literature, sometimes associated with higher increases in car ownership than the age group below.)

5.1 Basic proximity effect

5.1.1 General accessibility

Results regarding the overarching umbrella factor *general daily amenity accessibility* (specification in Table 4.3) are documented as Model 1 in Table 5.3 below and, for readability, also summarized in Table 5.1 right below. In accordance with ***hypothesis (Hvii)*** in section 2.2.1, there is a positive association between the distance to *general daily amenities* and household car ownership (which is statistically significant at the 1% significance level). For the preferred models, on average, an increase of 1 kilometre in the *general daily amenity distance* is associated with a significant 0.03 and 0.05 increase in household car ownership for the cross-sectional and panel analysis, respectively.

Table 5.1 Featured results for the relationship between (general) daily amenity distance and household car ownership

	Cross-sectional	**Panel**
Distance to [..]	(1)	(1)
Daily amenities	0.0282*** (0.00305)	0.0539*** (0.00806)
Controls	*YES*	*YES*
Individual FE	*NO*	*YES*
Time FE	*NO*	*YES*
Outlier filters	*YES*	*YES*

(Clustered) robust standard errors in parentheses: ***p<0.01, **p<0.05, *p<0.01

Notes: These results are an excerpt from Model 1 of Table 5.3 below.

These results reversely indicate that improved accessibility of *daily amenities* is significantly associated with decreased household car ownership levels, a (as further elaborated on in section 5.3), despite different effect sizes conclusion robust to various model specifications and sensitivity analyses.

Considering the average household car ownership of 0.919 and 0.912 for the cross-sectional (2019) and panel (2009-2019) analysis (Table 4.2), these effects translate into a relative decrease of 3.1% and 5.9% respectively. However, the average distance to *daily amenities* (umbrella factor) of 2.10 and 2.03 kilometre for the cross-sectional and panel analysis respectively (documented in Table 7.4 in the Appendix) implies that to achieve these reductions, distances should be approximately halved (47.6% and 49.3%). This can be considered a drastic decrease, implying that more feasible reductions are associated with relatively small reductions in household car ownership: When considering the average decrease in distance to *daily amenities* between waves (that is, 5-years) of 133 metres, this is associated with a 0.8% decrease in household car ownership ($\frac{0.0539 \times 0.133}{0.912} * 100\%$).

Following these relative effects, it is considered appropriate to state that the effects are small. While the premise elaborated on in section 2 stated that destinations in proximity should be preferred over distant ones, this relied on an "all else equal" assumption (Handy and Clifton, 2001; Meurs and Haaijer, 2001 in Elldér et. al., 2022). It must however be noted that this "all else equal" is unlikely to be present, as many of the amenities included are not homogenous. Therefore, when covering additional distance provides access to "better" amenities (*e.g., for restaurants referring to quality of the food, or prices*), these destinations might be preferred, despite their "long-distance" locations (Haugen et. al., 2012; Handy and Clifton, 2001; Naess et. al., 2019 in Elldér et. al., 2022). In practice, travel distance is therefore argued to be one of many factors influencing destination choice (Elldér et. al., 2022). In addition, section 2.0 cited several other factors able to influence car ownership, making travel distance not only *one of many factors* influencing destination choice, but also *one of many factors* influencing car ownership, together possibly explaining the small effects found.

5.1.2 Amenity factors

When detangling these *general amenity* results of section 5.1.1, Model 2 of Table 5.3 below documents results for different amenity groups/factors (summarized in Table 5.2 right below). In accordance with ***hypotheses (Hi – Hvi)*** in section 2.2.1, there is a positive association between all daily amenity distances and household car ownership (which is statistically significant at the 1% or 5% significance level) for either *(healthcare & catering)* or both (*retail, children, alternative mobility, leisure)* the cross-sectional and panel models. This reversely again indicates that improved accessibility of all daily amenity groups is significantly associated with decreased household car ownerships levels.

Table 5.2 right below summarizes results and indicates that for both the cross sectional and panel analysis, the decrease in household car ownership associated with a 1-kilometre decrease in distance is largest for *children related facilities* (coefficient of 0.06 and 0.04 at 1% significance level, respectively).

These effects are followed in magnitude by *retail* (coefficient of 0.02 at 1% significance level) and *catering* (coefficient of 0.03 at 1% significance level) for the cross-sectional and panel analysis respectively. Conversely, for both analyses the smallest household car reductions are associated with *leisure* (coefficient of 0.01 at 1% significance level for both models) and *alternative mobility* (coefficient of 0.002 at 1% (cross) and 5% (panel) for both models) related distance reductions. The same order of magnitude (and often considerable similar coefficients) moreover indicate that the effect size is similar for *between urban neighbourhoods* (cross sectional) and *within urban neighbourhoods* (panel) models.

While these factor effect sizes can however again be considered relatively small, considerable household car ownership decreases can be achieved through combination of multiple factors: when decreasing the distance to *all found to be significant* amenity groups with 1 kilometre, this is associated with a relative decrease in household car ownership of 13.0% and 11.8% respectively for the cross sectional and panel analysis (as documented in table 5.2 below).

When considering the descriptive statistics in Table 7.4 of the Appendix, the (hierarchy of) effect size (fairly similar for both models) moreover appears to correspond to average distances. That is, amenity groups that exhibit relatively short(/long) average distances are associated with larger(/smaller) car reduction possibilities.

Table 5.2 Featured results for the relationship between distance to specific (groups of) daily amenities and household car ownership

	Cross sectional				Panel			
Factor	**Coef.**	**Rank**	**Individuals**	**Rank**	**Coef.**	**Rank**	**Individuals**	**Rank**
Healthcare	0.0199***	*#3*	general practice**	#3			general practice**	#3
			pharmacy**	#4			pharmacy***	#1
			hospital***	#8				
Retail	0.0237***	*#2*	large supermarket***	#2	0.0241***	*#3*	department store**	#6
Catering			restaurant*	#6	0.0310***	*#2*	café**	#5
Children	0.0608***	*#1*	day-care***	#1	0.0394***	*#1*	primary education***	#2
			secondary education***	#7				
Alternative mobility	0.00173***	*#5*	train station***	#11	0.00233**	*#5*	important transfer station**	#7
Leisure	0.0132***	*#4*	library***	#5	0.0106***	*#4*	performing arts ***	#4
			performing arts***	#9				
			cinema***	#10				
Total	0.119 (13.0%)		0.1792 (19.5%)		0.107 (11.8%)		0.085 (9.3%)	

(Clustered) robust standard errors in parentheses: ***p<0.01, **p<0.05, *p<0.01

Notes: Note that these results are an excerpt from Model 2 and 3 of Table 5.3 below. "Total" refers to a summation (and relative indication compared to average household car ownership) of all found positive significant coefficients.

5.1.3 Individual amenities

When detangling these group effects of section 5.1.2, Model 3 of Table 5.3 below documents results for individual/distinct type distances (summarized in Table 5.2 right above). Here, there is for almost all individual daily amenity (except for *other shops for daily groceries, cafeteria, school care* and *swimming pool)* a positive association between distance and household car ownership (which is statistically significant at the 1%, 5% or 10% significance level), for either or both the cross and panel models. This conversely indicates again that improved accessibility of daily amenities is significantly associated with decreased household car ownership levels.

However, considerable **differences** appear both *within* the groups and *between* the models:

- Considering differences ***within groups***, these are particularly visible for *catering* in the cross-sectional analysis (as documented in Table 5.3 below): While the distance to *restaurants* is significantly (10% significance level) positively associated with car ownership, this effect is negative (5% significance level) for *cafe* and *cafeterias* (see point **c** below for possible explanation). Cancelling each other out, *catering* has no overall significant effect on household car ownership (however still in accordance with ***hypothesis (Hiii)***).

- Considering the differences ***between models*** elaborated on below, while almost all individual amenity distances are thus significantly associated with household car ownership in the expected direction, overall, the amenities of importance and their effect size can differ greatly between the cross sectional and panel models. While this implies that for reducing car ownership possibilities are virtually endless (as almost all have the desired effect *in one of the models)*, it also suggests that when an approach for reductions in both scenarios (between neighbourhoods and over time) is aspired, possibilities are limited to *general practice, pharmacy* and *performing arts* (see Table 5.2 above).

A: When explaining the (considerable similar) results for amenity factors (section 5.1.2), other explanatory individual amenity distances are found (as documented in Table 5.3 below and summarized in Table 5.2 above): While the overall positive significant effect of *retail* is entirely explained by distance to *large supermarket* for the cross-sectional analysis, for the panel analysis this refers to the distance to *department store.* Same rationale applies to *children related facilities* (*day care & secondary education* vs. *primary education), alternative mobility (train station* vs. *important transfer station)* and to a lesser extent to *healthcare and leisure.*

B: Also in terms of effect size hierarchy considerable differences exist between the cross sectional and panel model:

- ***Cross sectional*:** For the cross-sectional analysis decreased distance to *day care* (coefficient of 0.06)*, large supermarkets* (coefficient of 0.03) and *general practice* (coefficient of 0.02) are associated with largest household car ownership reductions (all at the 1% or 5% significance level, as documented in Table 5.3 below). This matches results for Model 2 elaborated on in section 5.1.2: That is, the large (significant) individual effects of *day care, large supermarkets,* and *general practice* (the latter together with *pharmacy*), "carry" the large (significant) factor effects of *children related facilities* (coefficient of 0.06)*, retail* (coefficient of 0.02) and *healthcare* (coefficient 0.02) respectively (also matching ranks, as indicated in Table 5.2 above). Again, effect size also approximately matches average distance: That is, average distances towards these (large effect) amenities are relatively small as documented in Table 7.4 in the Appendix. Although this might be surprising for the *large supermarkets,* CBS classifies "large" supermarkets as supermarkets with a minimum area of 150 m2 (see Table 7.4 in the Appendix; Centraal Bureau voor de Statiestiek (n.d.-g)) while the average area of Dutch supermarkets is estimated to be well over 900 m2 (Slob, 2020; Lubbers, 2018), resulting in the expectation that "most" supermarkets fit this classification.

- ***Panel*:** Conversely, for the panel analysis largest effect sizes are associated with distance towards *pharmacy* (coefficient of 0.02)*, primary education* (coefficient of 0.02) and *general practice* (coefficient of 0.01) (all at the 1% or 5% significance level, as documented in Table 5.3 below), and thus only the latter matches top-3 findings of the cross-sectional analysis. While these results again approximately match average distances, the effect of *pharmacy* and *general practice* is now insufficient to induce an overall positive *healthcare* effect (potentially hinting towards a small but vital influence of *hospital*).

C: In addition, there are differences between the two models for individual distance effects: Most drastically, where the association between distance to *café* and household car ownership is significantly (5%) <u>negative</u> for the cross-sectional analysis (indicated at the beginning of this section), this association is significantly (5%) <u>positive</u> for the panel analysis. *These unexpected negative effects may be related to the beliefs elaborated on in section 2.0 (e.g., car affinity or lack of ecological awareness (Witte et. al., 2022)) of the people living in such, by Aditjandra et. al., 2012 so-called "vibrant social/café-style areas, as the panel regression is expected to capture more of these beliefs through usage of fixed effects, compared to the cross-sectional regression (section 4.3.1).*

Overall, for the cross-sectional analysis, distance towards a larger range of individual amenity distances appears to be (significantly) positively associated with household car ownership, compared to the panel analysis (11 and 7, respectively: see Table 5.3 below and 5.2 above). Accordingly, relative reductions in household car ownership associated with a 1-kilometre decrease in *all found positive significant* *coefficients* are considerably larger for the cross-sectional analysis (as documented in Table 5.2 above, 19.5% versus 9.3%, compared to average car ownership levels).

Although **similarities** between the two models are thus scarce, for both models (documented in Table 5.3 below and summarized in Table 5.2 above) distance towards *general practice* and *pharmacy* provide relatively large (and significant) household car ownership reductions (following ranks documented in Table 5.2 above), providing a possible way of reducing car ownership in both specifications. While specific individual/distinct type effect size hierarchies thus differ, (see point **b** above), largest reductions for both can moreover be achieved (additionally approximately matching the relatively low average distances link argued before) in the *children* and *healthcare* segments. Conversely, distance to individual amenities that fall under *alternative mobility* are generally found to have relatively small significant effects for both (now matching the relatively high average distances in Table 7.4 of the Appendix).

Here, it must also be noted that, although having a small effect size for the cross-sectional model (matching the relatively large distance of Table 7.4 in the Appendix), *performing arts* provide the third opportunity to decrease car ownership in both comparisons (and is moreover the only robust one, as elaborated on in section 5.3).

Table 5.3 Regression results of the relationship between the distance to daily amenities and the number of cars per household

	Cross-sectional					Panel				
Distance to [..]	(1)	(2)	(3)	(2b)	(2c)	(1)	(2)	(3)	(2b)	(2c)
Daily amenities	0.0282***					0.0539***				
	(0.00305)					(0.00806)				
Healthcare		0.0199***		0.0367***	0.0208***		0.00553		0.0123	0.00309
		(0.00313)		(0.0123)	(0.00657)		(0.00502)		(0.0136)	(0.00760)
Healthcare²				-0.00393					-0.00176	
				(0.00264)					(0.00358)	
Healthcare * alternative mobility					-2.67e-06					0.000406
					(0.000619)					(0.000822)
General practice			0.0203**					0.0148**		
			(0.00818)					(0.00690)		
Pharmacy			0.0198**					0.0247***		
			(0.00806)					(0.00623)		
Hospital			0.00511***					-0.00190		
			(0.00104)					(0.00159)		
Retail		0.0237***		0.0394*	0.0238**		0.0241***		0.0156	0.0212*
		(0.00864)		(0.0228)	(0.0121)		(0.00740)		(0.0198)	(0.0117)
Retail²				-0.00991					0.00100	
				(0.00975)					(0.00814)	
Retail * alternative mobility					-0.000437					0.000452
					(0.00157)					(0.00187)
Large supermarket			0.0307***					0.00901		
			(0.0111)					(0.00883)		
Other shop for daily groceries			0.00472					0.0153		
			(0.0123)					(0.0110)		
Department store			-0.00292					0.00547**		
			(0.00343)					(0.00223)		
Catering		-0.000386		0.0820***	0.000891		0.0310***		0.129***	0.0558***
		(0.00900)		(0.0289)	(0.0151)		(0.00823)		(0.0232)	(0.0148)
Catering²				-0.0478***					-0.0568***	
				(0.0141)					(0.0114)	
Catering * alternative mobility					-0.000442					-0.00406*
					(0.00195)					(0.00208)
Cafes etc.			-0.00911**					0.00849**		
			(0.00408)					(0.00388)		
Cafeteria etc.			-0.0258**					-0.00139		
			(0.0126)					(0.0103)		
Restaurant			0.0133*					0.00164		
			(0.00794)					(0.00562)		

Children		0.0608***		0.140***	0.115***		0.0394***		0.0814***	0.0570***
		(0.00873)		(0.0318)	(0.0167)		(0.00934)		(0.0267)	(0.0155)
Children^2				-0.0435***					-0.0231	
				(0.0165)					(0.0140)	
Children * alternative mobility					-0.00830***					-0.00291
					(0.00196)					(0.00178)
Day-care			0.0568***					0.00785		
			(0.0146)					(0.00544)		
School care			0.0126					0.00799		
			(0.0129)					(0.00582)		
Primary education			-0.000819					0.0220***		
			(0.0116)					(0.00814)		
Secondary education			0.00689***					0.00312		
			(0.00264)					(0.00257)		
Alternative mobility		0.00173***		0.00512***	0.0123***		0.00233**		0.0103***	0.00781***
		(0.000483)		(0.00190)	(0.00159)		(0.000969)		(0.00277)	(0.00244)
Alternative mobility^2				-0.000163*					-0.000471***	
				(9.12e-05)					(0.000149)	
Train station			0.00182***					0.000614		
			(0.000649)					(0.00139)		
Important transfer station			0.000442					0.000885**		
			(0.000272)					(0.000440)		
Leisure		0.0132***		0.0228***	0.0259***		0.0106***		0.0227***	0.0145***
		(0.00194)		(0.00702)	(0.00417)		(0.00267)		(0.00752)	(0.00487)
Leisure^2				-0.00162*					-0.00224**	
				(0.000932)					(0.00103)	
Leisure * alternative mobility					-0.00144***					-0.000702
					(0.000364)					(0.000617)
Library			0.0169***					0.00130		
			(0.00292)					(0.00247)		
Performing arts			0.00469***					0.00859***		
			(0.00112)					(0.00190)		
Cinema			0.00289***					0.00171		
			(0.000951)					(0.00122)		
Swimming pool			0.00113					0.000848		
			(0.00159)					(0.00141)		
Constant	-1.181***	-1.194***	-1.187***	-1.293***	-1.246***	-0.958***	-0.925***	-0.907***	-0.990***	-0.942***
	(0.107)	(0.101)	(0.101)	(0.104)	(0.0997)	(0.165)	(0.160)	(0.154)	(0.154)	(0.155)
Number of observations	3,876	3,876	3,876	3,876	3,876	10,496	10,496	10,496	10,496	10,496
R2	0.765	0.775	0.780	0.777	0.778	0.819	0.823	0.825	0.825	0.824

Controls	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Individual FE	*NO*	*NO*	*NO*	*NO*	*NO*	*YES*	*YES*	*YES*	*YES*	*YES*
Time FE	*NO*	*NO*	*NO*	*NO*	*NO*	*YES*	*YES*	*YES*	*YES*	*YES*
Outlier filters	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*

(Clustered) robust standard errors in parentheses: ***p<0.01, **p<0.05, *p<0.01

5.2 Non-linearities

As determined in the previous section, there is a general small positive (and statistically significant) association between the proximity to daily amenities and the average number of cars per household in Dutch urban neighbourhoods. The next section will focus on the form of this relationship, concerning (i) diminishing sensitivity/decreasing returns and (ii) interaction with alternative mobility distance.

5.2.1 Diminishing sensitivity

Table 5.3 above documents results for Model 2b, which includes quadratic terms for all daily amenity factors. Following the results for the joint significance test of these 6 quadratic coefficients documented in row 1 of Table 5.4 below, a jointly significant (1% significance level) quadratic term of distance towards daily amenity (factors) is found for both the cross sectional and panel analysis. As this term is negative for all individual significant cases (see Table 5.3 above), this indicates together with the found positive "general term" (as elaborated on in section 5.1.2 and again found here) the presence of *diminishing sensitivity/decreasing returns*, matching ***hypothesis (Hviii)*** in section 2.3.1.

That is, sensitivity to distance in terms of changes in household car ownership, decreases when distances increase. This implies that

(i) greater car ownership reductions can be achieved with the same distance change in areas that are already well accessible, or

(ii) less easily accessible areas have to make greater efforts in terms of distance reduction for the same car ownership reduction.

Considering the results of Model 2b in Table 5.3 above (summary in Table 5.4 below), this joint significance likely results from *catering, alternative mobility, leisure,* and *children related facilities*, which have a significant quadratic term (and are jointly significant for their general and quadratic term) for either or both of the models.

Table 5.4 Joint significance results and switch of direction point for the diminishing sensitivity consideration (Model 2b)

	Cross sectional			Panel		
	F stat	**p-value**	**Switch at [..] km**	**F stat**	**p-value**	**Switch at [..] km**
(i) Diminishing sensitivity	6.02	0.000***		11.25	0.000***	
Catering	6.45	0.002***	0.86 (29.8%)	15.62	0.000***	1.14 (12.04%)
Children	26.91	0.000***	1.61 (1.32%)			
Alternative mobility	8.74	0.000***	15.71 (5.73%)	7.32	0.001***	10.93 (12.29%)
Leisure	20.40	0.000***	7.04 (0.34%)	6.53	0.002***	5.07 (5.29%)

Notes: The joint significance for (i) diminishing sensitivity refers to the joint significance of the 6 quadratic factors, while the joint significance for the individual factors refers to the joint significance for the general term and quadratic term for that factor. Switch additionally indicates at which distance the positive effect becomes negative due to the decreasing returns, and the percentage between brackets indicates for which share of the neighbourhoods studied this applies.

Eventually, these decreasing returns change the direction of the effect: For all joint significant (general and quadratic term) amenity groups, the switch point of effect-direction is documented in Table 5.4 above. For example, for distances over 1.61 kilometre, a cross-sectional decrease in distance towards *children related facilities* is associated with *increased* (rather than decreased) car ownership. Considering the distribution of distances, these points can be reached, but for all amenity factors this refers to a minority of the neighbourhoods studied (share for which negative effect applies is indicated between brackets in Table 5.4 above). Relationship form and applicability to the distribution is further elaborated on with Figure 5.1 and Figure 5.2 below.

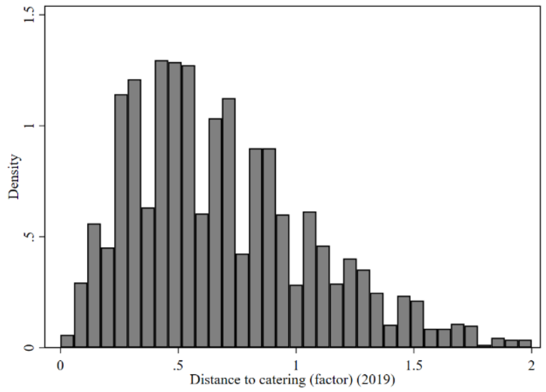


Figure 5.1 Distribution distance to catering (factor), 2019

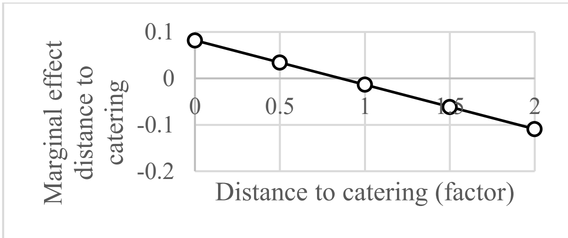


Figure 5.2 Illustration of the marginal effect of a 1-kilometre increase/decrease in distance to catering on household car ownership, depending on the distance to catering, for the cross sectional analysis (Model 2b). Determined as derivative from Table 5.3 above: marginal effect =

$$0.0820 - (2 \times 0.0478 * distance\ to\ catering)$$

While these negative effects might be somewhat counterintuitively, it might refer to "latent demand". *When facilities are located relatively far away, visiting them may not be worth it considering the distance. However, when this great distance decreases, it can "push people over the threshold" to go. Because this distance is still (relatively) large, these people will most likely need a car to cover this distance (rather than by e.g., bike or on foot), thus resulting in increased car ownership.*

5.2.2 Alternative mobility interaction

Table 5.3 above additionally documents results for Model 2c, which includes interaction terms for daily amenity factors with the alternative mobility factor. Following the results for the joint significance test of these 5 interaction terms documented in row 1 of Table 5.5 below, a jointly statistically significant (at the 1% significance level) interaction term between daily amenity and alternative mobility distance is found for both the cross sectional and panel analysis. As this term is negative for all individual significant factors (see Table 5.3), this indicates the presence of a *negative interaction effect with alternative mobility*, together with the found positive "general term" (elaborated on in section 5.1 above and again found here) matching ***hypothesis (Hix)*** in section 2.3.2.

That is, an increase in daily amenity accessibility (or a decrease in distance towards daily amenities) is associated with larger household car ownership decreases when the distance towards alternative mobility is smaller. This implies that when aiming to reduce car ownership with distances to daily amenities, reducing the distance towards alternative mobility besides inducing its own reduction (elaborated on in section 5.1.2) also strengthens the effect of "*other distances*". Considering that the joint significance likely results from *catering, leisure,* and *children related facilities* (which have a significant interaction term for either of the models as documented in Table 5.3 above), "*other distances*" refers mainly to distance towards these amenities in specific. It must however be noted that the representation of this effect is smaller than that of the *diminishing sensitivity* (now only present in 3/10 cases instead of 7/12), and explanatory factors differ fully between both analyses.

Ultimately, for large alternative mobility distances, the effect can again become negative (as indicated by the shares in brackets of Table 5.5 below, this again refers to a minority). While these effects might be counterintuitively, this might again refer to "latent demand". *When facilities are located relatively far away, visiting them may not be worth it, but when this distance decreases it can "push people over the threshold" to go. However, if alternative mobility is far away (and not a feasible option) people will most likely need a car to cover these distances.* Relationship form and applicability to the distribution is further elaborated with Figure 5.3 and Figure 5.4 below.

Table 5.5 Joint significance results and switch of direction point for alternative mobility interaction (Model 2c)

	Cross sectional			Panel		
	F stat	**p-value**	**Switch at [..] km**	**F stat**	**p-value**	**Switch at [..] km**
(ii) Alternative mobility interaction	12.23	0.000***		3.82	0.002***	
Catering				9.21	0.000***	13.74 (6.07%)
Children	29.24	0.000***	13.86 (8.05%)			
Leisure	24.77	0.000***	17.99 (3.02%)			

Notes: The joint significance for (ii) alternative mobility interaction refers to the joint significance of the 5 interaction terms between (other) daily amenity distance and alternative mobility distance, while the joint significance for the individual factors refers to the joint significance for the general term and interaction term for that factor. Switch additionally indicates at which distance the positive effect becomes negative due to the negative interaction terms and the percentage between brackets indicates for which share of the neighbourhoods studied this applies.

On the other hand, the found effect also indicates that the decrease in household car ownership associated with decreased distance to alternative mobility is bigger when the distance to amenities is smaller. *Intuitively, this could suggest that the accessibility of alternative mobility is pleasant, but of little (or, less) importance if this alternative mobility does not allow easy (or, short distance) destinations to be reached.* Here, "important" destinations thus refer to *catering, leisure* and *children related facilities.* (While also here negative effects are possible, these refer to drastic minorities: 0.2%, 2.3% and 0% respectively).

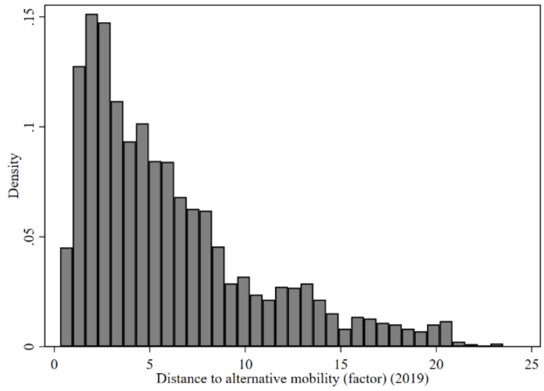


Figure 5.3 Distribution distance to alternative mobility (factor), 2019

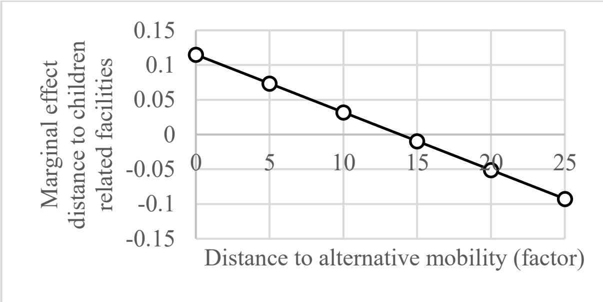


Figure 5.4 Illustration of the marginal effect of a 1-kilometre increase/decrease in distance to children related facilities on household car ownership, depending on the distance to alternative mobility, for the cross sectional analysis (Model 2c). Determined as derivative from Table 5.3 above: marginal effect =

$$0.115 - (0.0083 * distance\ to\ alternative\ mobility)$$

5.3 Considerations and estimation limitations

While the previous section highlighted the results of the preferred estimations models, several considerations indicate that these results should be interpreted with care. The following section therefore outlines findings from the model establishment and sensitivity analyses (note than when appropriate (e.g., not for outlier sensitivity) the same sample as for the preferred model is used to allow for comparison), the possibility of attrition bias, and the potential misspecification of the model.

5.3.1 Model establishment and sensitivity analyses

Basic proximity effect: General patterns that stand out when assessing the sensitivity analyses and different model specifications for the *basic proximity effect* (section 5.1) of Models 1 – 3 in Tables 7.6, 7.8, and 7.9 of the Appendix, are summarized in Table 5.6 below. The results are found to be considerable sensitive to the precise specification of the model which implies that caution is needed when interpreting them.

Table 5.6 General patterns associated with sensitivity analysis for the basic proximity effect (Model 1 – 3)

	Cross -sectional		Panel	
Establishment step/sensitivity	**effect size**	**significance**	**effect size**	**significance**
+ controls	Decreased	Lost	Decreased	Decreased
+ municipal FE			Decreased	Lost
+ time FE			Decreased	Cancels out
- outlier filters	Decreased	Cancels out	Cancels out	
+ population density	Decreased	Lost	Decreased	Cancels out
- other shop for daily groceries	Increased	Robust	Increased	Robust

Notes: Effect size and significance concerns the magnitude and significance level of the found positive coefficients matching hypotheses. "Cancels out" indicates that effect size increases and decreases, or significance gains and losses occur considerably equally often, while "robust" indicates little to no changes. Population density is moreover found to be (matching expectations based on literature in section 4.2.3) negatively (and statistically significantly) associated with household car ownership.

Table 5.7 below moreover indicates the positively significant effects robust to various model specifications and sensitivity analyses (for both or either of the cross sectional and panel models). Given their robustness, confidence in the conclusions of these is stronger.

Table 5.7 Robust effects for both or either the cross sectional and panel models

	Cross sectional	Panel
Model	**robust**	
Model 1	Daily amenities	
Model 2	Children related facilities, leisure, alternative mobility	
	Healthcare	
Model 3	Performing arts	
	Hospital, day-care, secondary education, train station, library	Pharmacy, important transfer station

Notes: Robust refers here to a found statistically significant and positive effect in all models (that is, model establishments (Table 7.6), sensitivity analysis (Table 7.8 & 7.9), and preferred models (Table 7.7).

Non-linearities: Table 5.8 below moreover documents joint significance robustness of the (i) diminishing sensitivity and (ii) alternative mobility considerations (section 5.2), indicating that their general presence (alternative mobility interaction to a lesser extent) is considerably robust. However, the factors exhibiting these relationships and their specific magnitude/form is again found to be sensitive to the specific model specifications (however, all significant non-linear terms are, matching ***hypotheses (Hviii & Hix)*** negative).

Note also that the results of the preferred *basic proximity* Models 1, 2 and 3 are, in terms of positively significant effects, largely robust to the inclusion of the squared and interaction term. While the significance levels and effect-magnitude can change, the only major differences are *retail* and *catering* losing and gaining its general term significance for the panel and cross-sectional preferred diminishing sensitivity analysis respectively (see Table 5.3 above, or Table 7.7 in the Appendix).

Table 5.8 Joint significance and number of terms subject to the considerations of (i) diminishing sensitivity and (ii) interaction with alternative mobility, for various sensitivity analyses

	Cross -sectional				Panel			
	sensitivity		**interaction**		**sensitivity**		**interaction**	
establishment step/sensitivity	**Sign.**	**#**	**Sign.**	**#**	**Sign.**	**#**	**Sign.**	**#**
preferred model	***	4	***	2	***	3	***	1
- outlier filters	***	5	***	3	***	3	***	2
+ population density	**	2	***	2	***	3		0
combination model	***	1	***	2	***	3	*	0

Notes: Significance concerns the joint significance of the 6 diminishing sensitivity and 5 interaction terms, while # refers to the number of factors exhibiting this relationship.

5.3.2 Attrition bias

While the most common availability pattern for the final dataset used in the panel analysis refers to presence in all three waves (2009-2014-2019), this is the case for 44.96% of the observations. Therefore, the dataset is unbalanced (units drop from the sample), and attrition is present. To determine the likelihood of attrition bias, a new variable indicating whether the neighbourhood is available in the *next wave* will be constructed and added to all ultimately preferred fixed-effects models with clustered standard errors.

The estimated coefficients of this variable (documented in Table 5.9 below) is statistically significant at the 5% significance level for all models, indicating that being present in the next wave is significantly (negatively) correlated with household car ownership levels and hinting that attrition is likely to be non-random: neighbourhoods with relatively high car ownership levels drop out and the determinant(s) of dropping out might also be correlated with variables of interest. *By way of illustration (and not necessarily true), it could be that neighbourhoods with decreasing population are more likely to drop out of the sample (due to "less important" notion). At the same time, in these neighbourhoods (i) distances to daily amenities might be higher because possible customer base is smaller, and (ii) average car ownership per household might be higher because social cohesion and cooperation is lower.* (The determinant of dropping out is therefore correlated with the variables of interest and a determinant of household car ownership, possibly inducing bias in the estimates).

Table 5.9 Regression results for the relationship between being in the next wave and household car ownership

	Panel				
	(1)	(2)	(3)	(2b)	(2c)
Next-wave	-0.030**	-0.028**	-0.026**	-0.030**	-0.028**
	(0.011)	(0.011)	(0.011)	(0.012)	(0.012)

Clustered (at municipal level) robust standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Notes: All models are similar to the preferred models elaborated on in section 5.1 and 5.2, now only adding a variable indicating whether the neighbourhood is present in the next wave.

5.3.3 Misspecification

To further assess the appropriateness of the model, a RESET test on incorrect/mis-specified functional form is applied for all preferred models (note that because this test is unsuited for a fixed effects regression, for the panel models a pooled OLS estimation is used as indication.) For all models (and additionally for model 2b/c including both considerations), the null-hypothesis that the model is well-specified can be rejected at the 1% significance level, which provides no evidence for a correct specification of the model. Therefore, again, conclusions made regarding the results of the analysis must be interpreted with care.

Although not in line with the hypotheses determined, currently unstudied interactions could be possible form-extensions worth exploring to achieve a well-specified model (further elaborated on in section 6.1).

6. Conclusion

High levels of car ownership are argued to be associated with increasing levels of car-based travel and related health and air quality problems (Handy et. al., 2005 in Potoglou and Kanaroglou, 2008). Following the aimed mobility transition away from cars of several Dutch cities (Gemeente Rotterdam, n.d.; Gemeente Amsterdam, n.d.; Folkers, 2021; Gemeente Leiden, n.d.; Gemeente Utrecht, 2022) and the argued ability of land-use decisions to considerably influence travel choices and transport options (Stevenson et. al., 2016), this research aspired to explore *how the accessibility of daily amenities (in terms of distance) influences (household) car ownership in Dutch urban neighbourhoods.* Using an Ordinary Least Squares cross-sectional and a Fixed Effects panel-based regression, the relationship between daily amenity distance ((overarching) factor or distinct type) and household car ownership in Dutch urban neighbourhoods is estimated.

While, matching ***hypothesis (Hvii)*** determined, the results for Model 1 in Table 5.3 indicate that there is robust positive association (significant at the 1% significance level) between *distance to daily amenities* and household car ownership both (i) compared to other neighbourhoods and (ii) over time, found effects are considered fairly small. For the preferred models (and on average), a decrease of 1 kilometre in the *general daily amenity distance* is associated with a significant 0.03 and 0.05 decrease in household car ownership for the cross-sectional and panel analysis, respectively. However, when translating into relative terms and considering the average decrease in distance to *daily amenities* between waves (of 5 years), this decrease of 133 metres is associated with a 0.8% decrease in average household car ownership. For policymakers aiming to drastically decrease car ownership levels in urban neighbourhoods, built-environment related policies in terms of accessibility are therefore unlikely to result in the desired (large) effects. Rather, measures related to other determinants of car ownership discussed in section 2 can be explored, for example referring to breaking the alleged prevailing social norm of car ownership (Witte et. al., 2022) or bending the notion of the car as a status symbol (CROW, 2016). Valuable follow-up research could therefore relate to other ways of reducing car ownership, and the size of these effects (compared to the distance effects found in this study).

If the built-environment nevertheless wants to be used to reduce car ownership (given the discussed size considerations, perhaps in combination with other measures), the following findings of this study can provide guidance.

(i) **Achieving large reductions*:*** First, as the associations found are thus rather small in size, when aiming for considerable car ownership reductions the results imply two "general" possibilities: (a) large decreases in distance, and/or (b) combination of several distance decreases. When combining these two, decreasing *all found to be significant* amenity groups/individual distances (for the preferred models) with 1 kilometre, this is associated with a relative decrease in household car ownership (expressed in percentages of the average household car ownership) of 13.0%/19.5% and 11.8%/9.3% respectively (see Table 5.2) for the cross sectional and panel analysis (which can be considered fairly large reductions).

Table 6.1 Summarizing factor and individual daily amenities associated with largest household car ownership reductions

	Cross sectional	Panel
Top-3 factors	1. Children related facilities (r+) 2. Retail 3. Healthcare (r-)	1. Children related facilities (r+) 2. Catering 3. Retail
Top-3 individuals	1. Day care (r-) 2. Large supermarket 3. General practice	1. Pharmacy (r-) 2. Primary education 3. General practice

Notes: (r+) indicates that the amenity(factor) is (in terms of having a positively significant coefficient) robust across all model specifications, while (r-) indicates that the amenity(factor) is robust across either all cross sectional or panel specifications. These top-3's are an expert from Table 5.2.

(ii) **Preferred policies - groups:** While all daily amenity group distances studied are, matching ***hypotheses (Hi – Hvi)*** determined, in Model 2 of Table 5.3 found to have the expected positive association with household car ownership (that is, increased accessibility is associated with decreased car ownership) for either or both the cross sectional and panel models, distance reductions to *children related facilities* (as a group) are for both comparisons associated with largest and robust car ownership reductions (while explanatory individual distances within this factor differ, see Table 5.2). Table 6.1 above provides a further summary of the largest (top 3) effect sizes and robustness for both model specifications, indicating preferred policy. Conversely, smallest effects (and therefore non-preferred policy) refers to *alternative mobility* (as a group, but also individual distances within, see Table 5.2 for a summary of effect sizes).

(iii) **– individuals:** Table 6.1 above additionally documents the largest (top 3) effect sizes (and robustness) for individual distances, again indicating preferred (when aiming for car ownership reduction) policies. While again almost all distances studied are found to have the expected positive association in Model 3 of Table 5.3, the amenities of importance can differ greatly, with a larger range of significant positive effects for the cross-sectional analysis (see summary in Table 5.2). While this implies that for reducing car ownership possibilities are virtually endless (as almost all have the desired effect *in one of the models)*, it also suggests that when an approach for reductions in both scenarios (between neighbourhoods and over time) is aspired, possibilities are limited to *general practice, pharmacy* and *performing arts* (the latter also being robust across all model specifications). On the contrary, distance reductions towards *café* and *cafeteria* are for the cross-sectional analysis associated with household car ownership *increases*, therefore relating to highly undesirable policy measures (that is, when aiming for car ownership reductions).

(iv) **Considerations:** While *alternative mobility* thus refers to a rather small association, its importance is not limited to its own effect, but the accessibility of alternative transport and other daily amenities reinforce each other when aiming to decrease household car ownership (see Table 5.3 Model 2c and Table 5.5 for which factors in specific this applies). Therefore, matching ***hypothesis (Hix)***, an increase in daily amenity accessibility is (quite robustly) associated with larger household car ownership decreases when the distance towards alternative mobility is smaller (and vice versa). This indicates that in the pursuit of reducing household car ownership, a combination of both offers opportunities.

(v) Additionally, *diminishing sensitivity* (quite robustly) appears to be present (matching ***hypothesis (Hviii)***): sensitivity to distance in terms of changes in household car ownership decreases when distances increase (see Table 5.3 Model 2b and Table 5.4 for which factors in specific this applies). This implies that (i) on the one hand, greater car ownership reductions can be achieved with the same distance change in areas that are already easily accessible, or (ii) on the other hand, less easily accessible areas have to make greater efforts in terms of distance reduction for the same car ownership reduction.

6.1 Critical reflection and follow-up suggestions

Although this study thus aimed to quantify a causal relationship between the distance to various daily amenities and car ownership in Dutch urban neighbourhoods, several limitations (some already discussed in section 5.3.) could prevent its realization (hence, the usage of *association* rather than *causal effect* throughout the report) and results should be interpret (and, perhaps, applied) with caution.

Bias: While including a range of control variables and fixed effects intended to account for possible bias, this is likely insufficient as the model (as argued in section 4.3.1) is always unable to account for factors (not specifically controlled for) that change over time *and* are different across municipalities (derived from Hanck et. al., 2023). Several of the "other" factors than can influence car ownership discussed in section 2.0 might fit this description, for example referring to affinity with cars, or ecological awareness (Witte et. al., 2022). When these factors are also correlated with the distance to amenities (which can be expected following self-selection arguments in which people who desire active travel modes (e.g., because of ecological awareness or non-affinity with cars) can be more inclined to live in neighbourhoods with associated amenities (Elldér et. al., 2022)), this can bias the estimates retrieved. Although (as argued in section 4.2.3) the inclusion of sociodemographic controls is argued to prevent some of this potential bias (Brownstone and Golob, 2009 in Elldér et. al., 2022), it might not capture all of it.

Additionally, the possibility of reverse causality must be considered (e.g., following the argued two-way link between transportation and land-use (Medda and Boarnet, 2003 in Donaghy et. al., 2004)):

Although this study aimed to quantify the influence of proximity to daily amenities on car ownership, the reverse is not inconceivable. *To illustrate (and not necessarily true), because few people in a neighbourhood have a car, amenities might be placed relatively close to people's home, because they simply cannot reach them otherwise.* With regard to these bias possibilities (reversed causality, omitted variable bias, but also the attrition bias elaborated on in section 5.3.2), it might be a valuable follow-up study to investigate this research question with a method able to (partially) overcome these limitations (e.g., referring to the usage of an instrumental variable or even an experiment setting, which are not employed in this study due to the lack of a suitable situation or instrument).

External validity: Considering the external validity, generalization to urban neighbourhoods in other countries could be problematic, given the relative compactness of the Netherlands, sensitivities to distance changes might be very different in, for example, the United States. Valuable follow-up research might therefore relate to geographical extensions of this research question. Related, generalization of the urban-based results to *rural* neighbourhoods could be problematic: people in rural areas (with generally larger distances as discussed in section 3.2) (i) might be more/less sensitive to distance changes and/or (ii) have different preferences and beliefs, resulting in possible different results and valuable follow-up research.

Applicability: Regardless of the (unbiasedness and/or external validity of) results, the possibility to influence the location of amenities can be limited. While public sector related amenities such as healthcare centres or schools could possibly be influenced through planning (which would be good news considering *children related facilities* having relatively large effects), most services are market sector related (Elldér et. al., 2022). Accordingly, the question is whether the study can make the aimed contribution of helping planners to reduce car ownership: while the results may indicate that amenity proximity is able to reduce car ownership (albeit, having small effects), when the location of these amenities (and thus distance) cannot (easily) be influenced, does this matter?

Data limitations: As argued, the premise that *distance to amenities* is the most adopted attribute related to accessibility (as discussed in section 2.2 by Fonseca et. al. (2022)) justifies the usage of an "average distance in kilometres over paved roads" measure (elaborated on in section 4.2.2) for accessibility. However, it can be interesting to explore the research question with different accessibility measures, such as time. Similarly, it must be noted that this measure "over paved roads used by cars" is focussed on the car (as this research involves local distances, it is expected that roads passable by cars are also largely passable by cyclists and pedestrians, although this may not be the shortest route for them). Therefore, exploring the research question with more comprehensive or multiple distance measures (the latter e.g. including distance by car, by bike, on foot and with public transport) could again provide a valuable research extension. Additionally, a research on an individual rather than neighbourhood level might be able to capture now "underlying lost processes" due to aggregation.

Moreover, the limitations associated with the data used: (i) the possibly by leasing or rental companies distorted car ownership figures elaborated on in section 4.2.1, (ii) the “considered” comparable sample selection of section 3.2, and (iii) the slightly different definitions for the independent variables between specific CBS information documents and years (indicated in Tables 7.4 and 7.5 in the Appendix), might influence the results. While associated problems are considered to be small (for the former e.g., considering the maximum value of 2.5 for the number of cars per household), the specific extent of this influence is difficult to assess.

Research extensions: Finally, the results of the research give rise to several possible follow-up studies.

While the derived demand characteristics of travel resulted in the premise that locations in proximity should be preferred over distant ones, this relied on an “all else equal” assumption (Handy and Clifton, 2001; Meurs and Haaijer, 2001 in Elldér et. al., 2022). However, this “all else equal” is unlikely to be present as amenities are unlikely to be homogenous. Therefore, when covering additional distance provides access to “better” amenities, these destinations might be preferred, despite their “long-distance” locations (Haugen et. al., 2012; Handy and Clifton, 2001; Naess et. al., 2019 in Elldér et. al., 2022). As the results indicate that *distance* towards daily amenities have rather small associations with household car ownership, also the quality of these amenities could be considered, possibly relating to a valuable follow-up research (following the relatively large and robust effects found associated with *children related facilities* e.g., research on the importance of the quality of these facilities).

Similarly, judging by the different "purposes of journeys" discussed by Metz (2010) and the places of importance for the compact city discussed by Aditjandra et. al. (2012), daily amenities may not be the only destinations that matter/the destinations that matter most (considering small associations): consider, for example, employment locations (Aditjandra et. al., 2012) or the location of friends (Metz, 2010) and family.

Moreover, while the results indicated the presence of a jointly-significant interaction effect between distances to alternative mobility and other daily amenities, this interaction effect relied solely on distance towards *train stations*. Research on a possible interaction effect with e.g., shared transport accessibility (following Klimaatweb (2021) in section 2.3.2), or bicycle ownership might provide a valuable extension. Similarly, other group interaction effects (e.g., between *catering* and *retail*) or interaction effects at the individual level (e.g., *large supermarket* and *day-care*), might provide valuable insights into both preferred policies aiming to reduce car ownership and well-specified model-forms (the latter referring to misspecification concerns raised in section 5.3.3). The same argument holds for e.g., an interaction with non-distance related variables, such as income.

7. Appendix

7.1 Literature review summary

Table 7.1 Earlier (in literature) found relationships between amenity accessibility/distance etc. and (household) car ownership

Factor/amenity	**Hypothesized direction of relationship**	**Based on**	
increased distance to [..]	***[increased/decreased] car ownership***	***research on***	***by***
Healthcare	+		
Healthcare	+	Accessibility	Liu et. al. (2022)
Retail	+		
Shopping	+	(Moving to) Accessibility	Aditjandra et. al. (2012)
		Proximity	Li and Zhao (2017)
		Availability within walking distance	Woldeamanuel et. al. (2009)
Catering	?		
Vibrant social area	+	Moving to	Aditjandra et. al.(2012)
Restaurants	x	Number of	Li and Zhao (2017)
Bars and cafes	x	Availability within walking distance	Woldeamanuel et. al. (2009)
Children related facilities	+		
Children mobility	+	Time to school	Mc Donald et. al. (2008)
		Distance	Zwerts and Wets (2006)
Alternative mobility	+		
Bus stop	+	Availability within walking distance	Woldeamanuel et. al. (2009)
		Number within distance	Potoglou and Kanaroglou (2008)
Tram service/ U-bahn / S-bahn	+	Availability within walking distance	Woldeamanuel et. al. (2009)
Metro stop	+	Distance	Zegras (2010)
Leisure activities	?		
Cinema	+	Availability within walking distance	Woldeamanuel et. al. (2009)
Theatre	+		
Sport activities	x		

Notes: A "+" and "-" indicates increased and decreased car ownership associated with increased [distance/accessibility etc], respectively. An "x" indicates a found non-significant relationship.

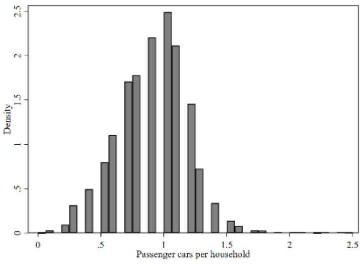
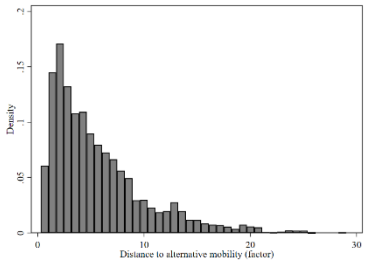
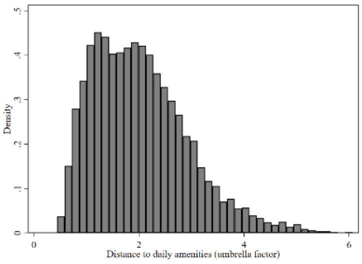
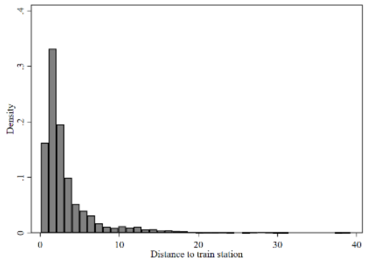
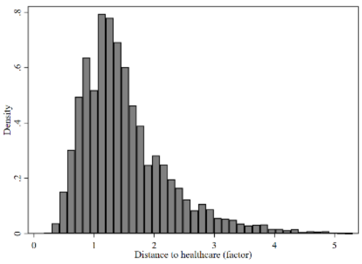
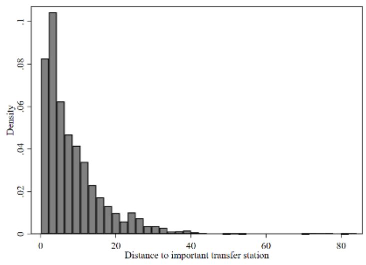
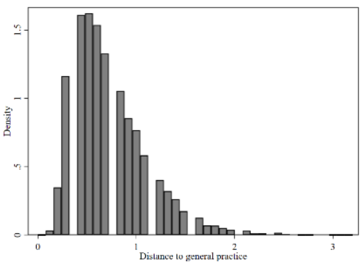
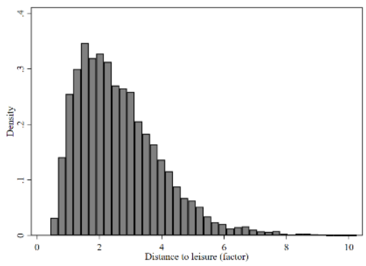
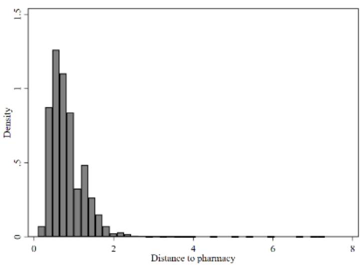
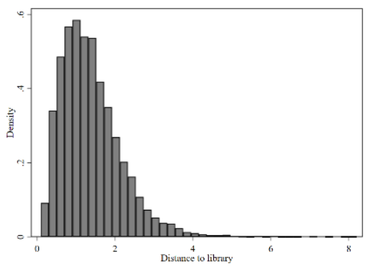
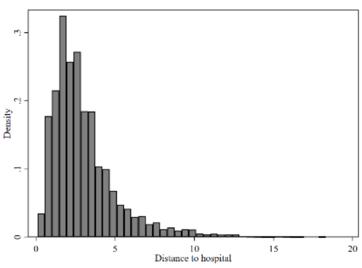
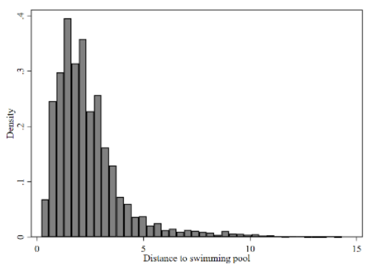
Table 7.2 Earlier (in literature) found relationships between other (non-distance related) factors and car ownership

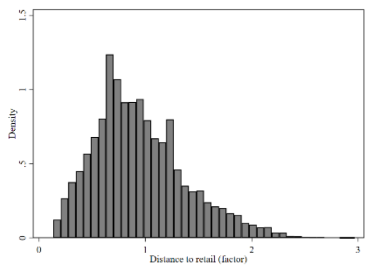
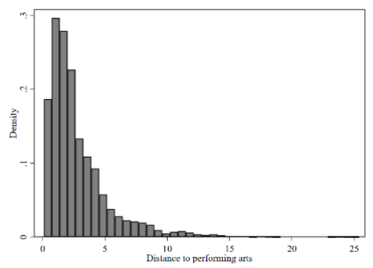
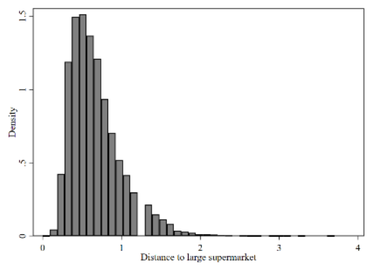
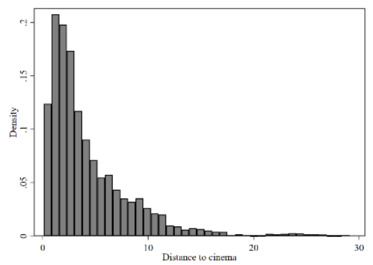
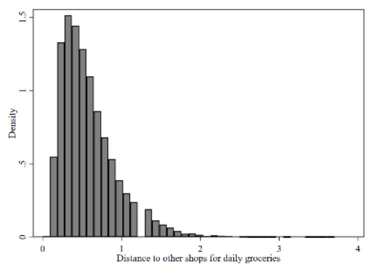
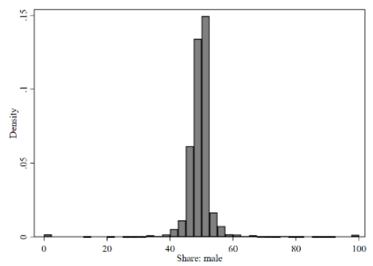
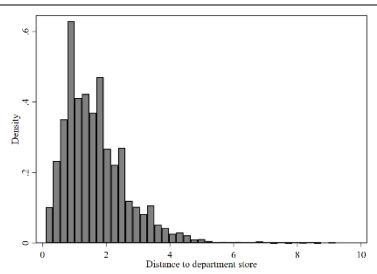
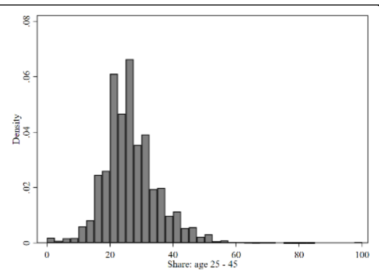
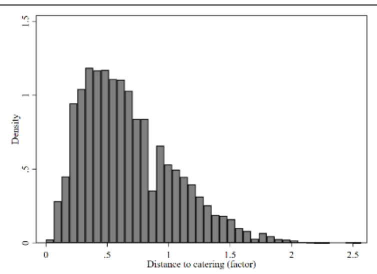
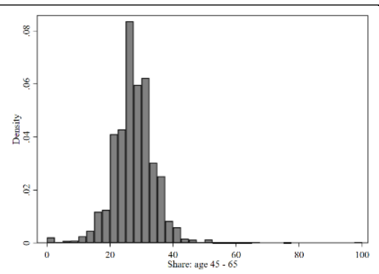
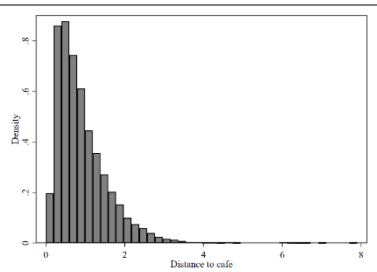
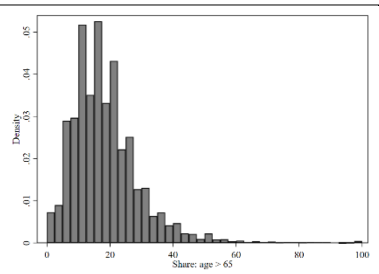
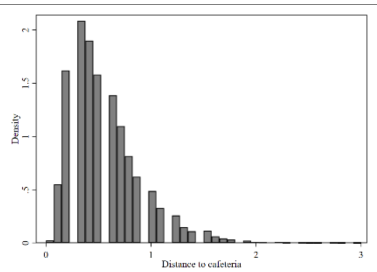
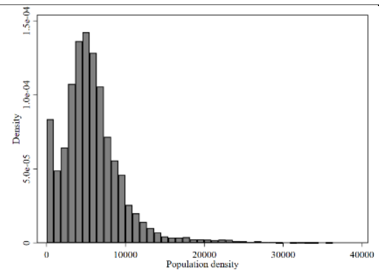
Increased [factor]	***[increased/decreased] car ownership***	**Source**
Age	+/-	Van Acker and Witlox (2010); Nolan (2010); Oakil et. al. (2016)
Female	-	Van Acker and Witlox (2010); Witte et. al. (2022)
Migration background	-	Mattioli and Scheiner (2022)
Employment	+	Nolan (2010)
Income	+	Zegras (2010); Li and Zhao (2017); Aditjandra et. al.(2012)
Household size	+	Van Acker and Witlox (2010); Li and Zhao (2017); Aditjandra et. al. (2012); Nolan (2010); Oakil et. al., (2016)
Safety	+	Aditjandra et. al. (2012)
Apartment living	-	Zegras (2010)

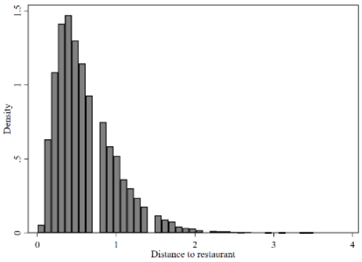
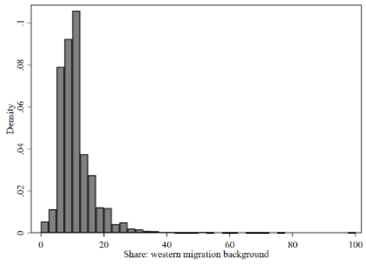
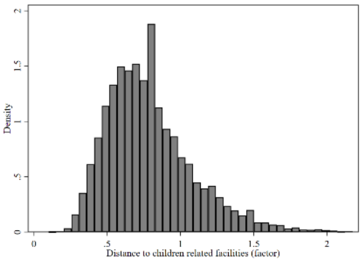
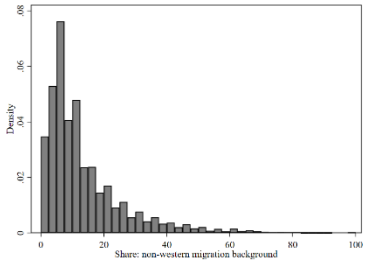
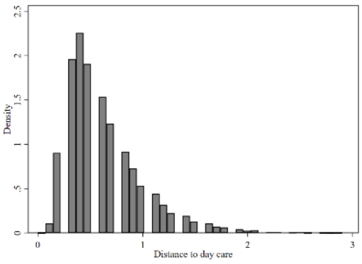
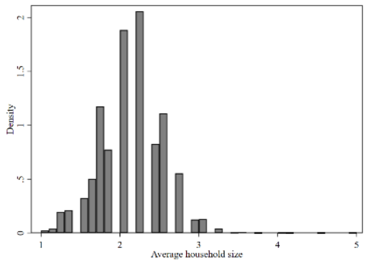
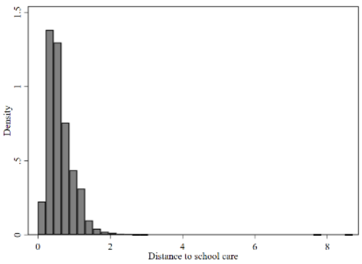
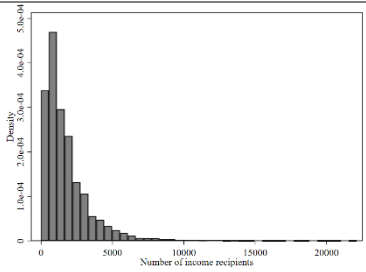
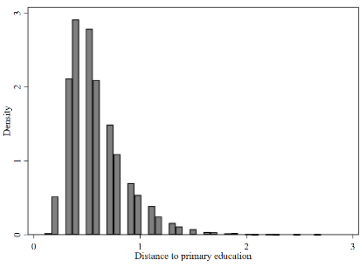
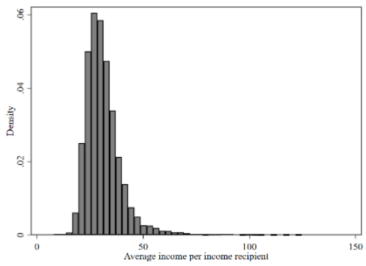
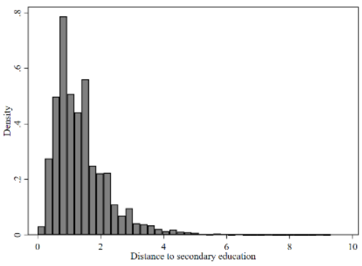
Notes: A "+" and "-" indicates increased and decreased car ownership associated with increased [factor], respectively. A "x" indicates a found non-significant relationship.

7.2 Descriptive statistics and outlier filters

Table 7.3 Outlier filters applied

Variable	Histogram (2009-2019)	Drop if value […]	Variable	Histogram (2009-2019)	Drop if value […]
Number of cars per household		>2	**Alternative mobility** (distance to)		>25
Umbrella (distance to)		>6	(distance to) Train station		>20
Healthcare (distance to)		>5	(distance to) Important transfer station		>40
(distance to) General practice		>2.5	**Leisure** (distance to)		>8
(distance to) Pharmacy		>3	(distance to) Library		>5
(distance to) Hospital		>13	(distance to) Swimming pool		>10

Retail (distance to)		>2.5	(distance to) Performing arts		>15
(distance to) Large supermarket		>2.5	(distance to) Cinema		>20
(distance to) Other shop for daily groceries		>2.5	Gender: male		<25 | >75
(distance to) Department store		>6	Age 25-45		>60
Catering (distance to)		>2	Age 45-65		>60
(distance to) Cafes etc.		>4	Age > 65		>60
(distance to) Cafeteria etc.		>2.5	Population density		>20,000

(distance to) Restaurant		>2.5	Western		>40
Children (distance to)		>2	Non-western		>70
(distance to) Day care		>2	Household size		>3.5
(distance to) School care		>3	Number of income recipients		>10,000
(distance to) Primary education		>2	Income per income recipient		>75
(distance to) Secondary education		>6			

Notes: Outlier filters for the distance variables are applied in the following sequence: (i) apply outlier filters for individual/ non-factor variables, (ii) create first level factor variables, (iii) apply outlier filters for first level factor variables, (iv) create umbrella factor, (v) apply outlier filter for umbrella factor.

Table 7.4 Descriptive statistics and definition of the variables of interest, for the years 2009, 2014 and 2019

		2009, 2014, 2019					2019
Distance to [..]	**Definition**	**N**	**Mean**	**Sd**	**Min**	**Max**	**Mean**
Umbrella		10,510	2.028	.905	.443	5.993	2.095
Healthcare		10,510	1.512	.727	.167	4.967	1.527
General practice		10,510	.705	.353	0	2.5	.73
Pharmacy		10,510	.803	.386	.1	3	.823
Hospital		10,510	3.028	2.001	.2	12.9	3.027
Retail		10,510	.948	.427	.133	2.5	.949
Large supermarket	Here, “large” refers to a minimum area of 150 m2.	10,510	.65	.315	0	2.4	.652
Other shop for daily groceries	This includes: greengrocer, pie shop, chocolate shop, deli, mini supermarket, poulterer, butcher shop, tobacconist, confectionary shop, free accessible shop on the campsite, baker, toko, coffee/tea shop, cheese shop, nut shop, health food shop, liquor store, fishmonger, and hospital shop.	10,510	.553	.34	0	2.5	.565
Department store		10,510	1.64	.938	.2	6	1.631
Catering		10,510	.67	.374	0	2	.684
Cafes etc.	This includes: Café, coffee shop, sex/night club, coffee house, discotheque and party centre.	10,510	.859	.617	0	4	.903
Cafeteria etc.	This includes: Fast food restaurant, lunchroom, ice cream parlour, grill room/shoarma shop, and pancake house.	10,510	.542	.321	0	2.4	.542
Restaurant	This includes: Restaurant, takeaway/home delivery, and café-restaurant.	10,510	.609	.383	0	2.5	.607
Children		10,510	.785	.293	.1	2	.743
Daycare	Place where children ranging from 0 to 4 years old are cared for throughout the year, one or more half-days per week.	10,510	.611	.333	.1	2	.497
School care	Place where children of primary school ages are cared for (e.g. after/before school or during the holidays, etc.).	10,510	.61	.316	.1	3	.568
Primary education	Also includes so-called “driving schools”, schools for children without fixed residence and mooring schools for sailing children.	10,510	.568	.251	.1	2	.594
Secondary education	Does not include special and practical schools.	10,510	1.351	.846	.1	6	1.312
Alternative mobility		10,510	5.628	4.39	.3	25	6.103
Train station		10,510	3.191	3.169	.2	19.7	3.279
Important transfer station		10,510	8.065	7.12	.3	40	8.927

Leisure		10,510	2.625	1.313	.425	7.975	2.566
Library		10,510	1.404	.737	.2	5	1.483
Performing arts	Art forms performed in front of a live audience, by actors and actresses, does not include festivals.	10,510	2.696	2.215	.1	15	2.709
Cinema		10,510	4.031	3.336	.1	18.9	3.774
Swimming pool		10,510	2.37	1.517	.2	10	2.3

Notes: Descriptive statistics are retrieved after *applying outlier filters/sample selection and definitions are retrieved from Centraal Bureau voor de Statistiek (n.d.-g) (note that these concern "general" definitions and that definitions can differ slightly between specific CBS information documents and/or years).*

Table 7.5 Descriptive statistics and definition of independent control variables, for the years 2009, 2014 and 2019

		2009, 2014, 2019				
Variable	**Definition**	**N**	**Mean**	**Sd**	**Min**	**Max**
Population	Number of inhabitants that fit a certain description on January 1st, expressed in whole percentages of the total number of inhabitants.					
Gender: male		10,510	49.075	2.59	28	75
Age 25-45		10,510	26.431	7.711	4	60
Age 45-65		10,510	27.311	5.844	0	51
Age > 65		10,510	18.231	9.675	0	60
Western	Europe, Oceania, Japan, North America, and Indonesia	10,510	10.801	4.741	0	40
Non-western	Turkey, Latin America, Africa, and "other" Asia	10,510	13.414	12.034	0	70
Population density	Number of inhabitants per square kilometre.	10,510	5952.352	3155.374	50	19898
Household size	The number of persons living in private households divided by the number of private households.	10,510	2.13	.378	1	3.5
Income						
Number of income recipients	Number of people in private households with personal income (rounded to hundreds).	10,510	1829.22	1523.097	100	10000
Average income per income recipient	Average personal income per person based on people in private households with personal income (x 1,000 euros).	10,510	31.111	8.019	7.9	74.9

Notes: These descriptive statistics are retrieved after *applying outlier filters/sample selection and definitions are retrieved from Centraal Bureau voor de Statistiek (n.d.-i; n.d.-j; n.d.-k) (note also that these concern "general" definitions and that definitions can differ slightly between specific CBS information documents and/or years).*

7.3 Model establishment

Table 7.6 Full regression results of the basic relationship between the distance to daily amenities and the number of cars per household, without control variables and/or fixed effects

	Cross sectional			Panel								
	No controls			No controls, no fixed effects			Controls, no fixed effects			Controls, only municipal fixed effects		
Distance to [..]	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Daily amenities	0.140***			0.140***			0.0328***			0.0531***		
	(0.00442)			(0.0148)			(0.00508)			(0.00781)		
Healthcare		0.0583***			0.0399***			0.0146***			0.00669	
		(0.00505)			(0.00884)			(0.00451)			(0.00522)	
General practice			0.0495***			0.0400**			0.0172*			0.0174**
			(0.0143)			(0.0175)			(0.00964)			(0.00674)
Pharmacy			0.0248*			0.0341**			0.0297***			0.0248***
			(0.0138)			(0.0133)			(0.00812)			(0.00621)
Hospital			0.0147***			0.00971***			0.00304**			-0.00185
			(0.00173)			(0.00296)			(0.00148)			(0.00162)
Retail		0.0274**			0.0410**			0.0233***			0.0228***	
		(0.0119)			(0.0171)			(0.00782)			(0.00736)	
Large supermarket			0.108***			0.104***			0.0204*			0.00961
			(0.0189)			(0.0196)			(0.0106)			(0.00886)
Other shop for daily groceries			0.00425			0.0200			0.0220*			0.0161
			(0.0214)			(0.0183)			(0.0131)			(0.0109)
Department store			-0.0129***			-0.00503			-0.00152			0.00378
			(0.00496)			(0.00701)			(0.00296)			(0.00231)
Catering		0.181***			0.188***			0.00997			0.0361***	
		(0.0133)			(0.0216)			(0.0103)			(0.00815)	
Cafes etc.			0.0181***			0.0271***			-0.00535			0.0100**
			(0.00686)			(0.00928)			(0.00487)			(0.00389)
Cafeteria etc.			0.0944***			0.0888***			-0.0350**			-0.00309
			(0.0201)			(0.0207)			(0.0141)			(0.0103)
Restaurant			0.0703***			0.0537***			0.0120*			0.00209
			(0.0135)			(0.0148)			(0.00694)			(0.00569)
Children		0.135***			0.120***			0.0524***			0.0366***	
		(0.0145)			(0.0191)			(0.0103)			(0.00956)	
Day care			0.149***			0.0581***			0.00819			0.00267
			(0.0221)			(0.0162)			(0.00671)			(0.00525)

School care	-0.0258	-0.00925			0.0106			0.00446
	(0.0178)	(0.0141)			(0.0111)			(0.00591)
Primary education	-0.0747***	-0.00386			0.0361***			0.0261***
	(0.0189)	(0.0198)			(0.00951)			(0.00785)
Secondary education	0.0361***	0.0269***			0.00639*			0.00413
	(0.00437)	(0.00582)			(0.00333)			(0.00262)
Alternative mobility	0.00979***	0.0107***		0.00292***			0.00302***	
	(0.000786)	(0.00171)		(0.000937)			(0.00103)	
Train station	0.00509***	0.00437**			0.00204*			0.000647
	(0.00108)	(0.00192)			(0.00120)			(0.00144)
Important transfer station	0.00388***	0.00504***			0.00119**			0.00106**
	(0.000449)	(0.00107)			(0.000533)			(0.000464)
Leisure	0.0369***	0.0325***		0.0115***			0.00818***	
	(0.00306)	(0.00535)		(0.00299)			(0.00294)	
Library	0.0115**	0.00969*			0.0132***			0.00323
	(0.00538)	(0.00580)			(0.00341)			(0.00247)
Performing arts	0.0140***	0.0115***			0.00360**			0.00891***
	(0.00184)	(0.00264)			(0.00163)			(0.00202)
Cinema	0.00847***	0.00764***			0.00225**			0.000847
	(0.00135)	(0.00218)			(0.00112)			(0.00142)
Swimming pool	-0.00203	0.00356			0.00500**			-0.000334
	(0.00258)	(0.00323)			(0.00213)			(0.00137)
Controls								
Gender: male			0.0158***	0.0154***	0.0145***	0.0133***	0.0131***	0.0126***
			(0.00249)	(0.00247)	(0.00234)	(0.00113)	(0.00122)	(0.00120)
Age 25 – 45			0.00161	0.00196	0.00201	0.00104	0.00120	0.00123
			(0.00235)	(0.00215)	(0.00207)	(0.00164)	(0.00156)	(0.00151)
Age 45 – 65			0.00753***	0.00731***	0.00745***	0.00584***	0.00582***	0.00595***
			(0.00181)	(0.00171)	(0.00164)	(0.00138)	(0.00132)	(0.00126)
Age > 65			0.00793***	0.00815***	0.00824***	0.00516***	0.00532***	0.00525***
			(0.00135)	(0.00122)	(0.00118)	(0.00113)	(0.00104)	(0.001000)
Western migration background			-0.00121	-0.00186	-0.00206	-0.00751***	-0.00751***	-0.00743***
			(0.00182)	(0.00176)	(0.00170)	(0.00132)	(0.00131)	(0.00127)
Non-western migration background			-0.00418***	-0.00400***	-0.00390***	-0.00257***	-0.00251***	-0.00254***

							(0.000417)	(0.000417)	(0.000388)	(0.000253)	(0.000225)	(0.000212)
Household size							0.443***	0.415***	0.422***	0.345***	0.326***	0.326***
							(0.0199)	(0.0194)	(0.0179)	(0.0191)	(0.0176)	(0.0161)
Income per income recipient							0.00358***	0.00399***	0.00380***	0.00787***	0.00789***	0.00762***
							(0.000917)	(0.000870)	(0.000824)	(0.000558)	(0.000521)	(0.000515)
Number of income recipients							-7.00e-06***	-6.84e-06***	-5.93e-06***	-1.03e-05***	-9.54e-06***	-8.40e-06***
							(1.84e-06)	(1.80e-06)	(1.70e-06)	(1.63e-06)	(1.79e-06)	(1.94e-06)
Constant	0.627***	0.426***	0.460***	0.629***	0.447***	0.450***	-1.296***	-1.304***	-1.294***	-0.975***	-0.951***	-0.921***
	(0.0104)	(0.0134)	(0.0151)	(0.0403)	(0.0389)	(0.0373)	(0.202)	(0.192)	(0.188)	(0.168)	(0.163)	(0.156)
Number of observations	3,876	3,876	3,876	10,496	10,496	10,496	10,496	10,496	10,496	10,496	10,496	10,496
R2	0.217	0.352	0.388	0.225	0.354	0.378	0.755	0.763	0.768	0.818	0.821	0.824
Controls	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Individual FE	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*YES*	*YES*	*YES*
Time FE	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
Outlier filters	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*

(Clustered) robust standard errors in parentheses: ***p<0.01, **p<0.05, *p<0.01

7.4 Full results preferred models

Table 7.7 Full regression results of the relationship between the distance to daily amenities and the number of cars per household for the preferred models

	Cross-sectional					Panel				
Distance to [..]	(1)	(2)	(3)	(2b)	(2c)	(1)	(2)	(3)	(2b)	(2c)
Daily amenities	0.0282*** (0.00305)					0.0539*** (0.00806)				
Healthcare		0.0199*** (0.00313)		0.0367*** (0.0123)	0.0208*** (0.00657)		0.00553 (0.00502)		0.0123 (0.0136)	0.00309 (0.00760)
Healthcare²				-0.00393 (0.00264)					-0.00176 (0.00358)	
Healthcare * alternative mobility					-2.67e-06 (0.000619)					0.000406 (0.000822)
General practice			0.0203** (0.00818)					0.0148** (0.00690)		
Pharmacy			0.0198** (0.00806)					0.0247*** (0.00623)		
Hospital			0.00511*** (0.00104)					-0.00190 (0.00159)		
Retail		0.0237*** (0.00864)		0.0394* (0.0228)	0.0238** (0.0121)		0.0241*** (0.00740)		0.0156 (0.0198)	0.0212* (0.0117)
Retail²				-0.00991 (0.00975)					0.00100 (0.00814)	
Retail * alternative mobility					-0.000437 (0.00157)					0.000452 (0.00187)
Large supermarket			0.0307*** (0.0111)					0.00901 (0.00883)		
Other shop for daily groceries			0.00472 (0.0123)					0.0153 (0.0110)		
Department store			-0.00292 (0.00343)					0.00547** (0.00223)		
Catering		-0.000386 (0.00900)		0.0820*** (0.0289)	0.000891 (0.0151)		0.0310*** (0.00823)		0.129*** (0.0232)	0.0558*** (0.0148)
Catering²				-0.0478*** (0.0141)					-0.0568*** (0.0114)	
Catering * alternative mobility					-0.000442 (0.00195)					-0.00406* (0.00208)

Cafes etc.		-0.00911**				0.00849**		
		(0.00408)				(0.00388)		
Cafeteria etc.		-0.0258**				-0.00139		
		(0.0126)				(0.0103)		
Restaurant		0.0133*				0.00164		
		(0.00794)				(0.00562)		
Children	0.0608***		0.140***	0.115***	0.0394***		0.0814***	0.0570***
	(0.00873)		(0.0318)	(0.0167)	(0.00934)		(0.0267)	(0.0155)
Children^2			-0.0435***				-0.0231	
			(0.0165)				(0.0140)	
Children * alternative mobility				-0.00830***				-0.00291
				(0.00196)				(0.00178)
Day care		0.0568***				0.00785		
		(0.0146)				(0.00544)		
School care		0.0126				0.00799		
		(0.0129)				(0.00582)		
Primary education		-0.000819				0.0220***		
		(0.0116)				(0.00814)		
Secondary education		0.00689***				0.00312		
		(0.00264)				(0.00257)		
Alternative mobility	0.00173***		0.00512***	0.0123***	0.00233**		0.0103***	0.00781***
	(0.000483)		(0.00190)	(0.00159)	(0.000969)		(0.00277)	(0.00244)
Alternative mobility^2			-0.000163*				-0.000471***	
			(9.12e-05)				(0.000149)	
Train station		0.00182***				0.000614		
		(0.000649)				(0.00139)		
Important transfer station		0.000442				0.000885**		
		(0.000272)				(0.000440)		
Leisure	0.0132***		0.0228***	0.0259***	0.0106***		0.0227***	0.0145***
	(0.00194)		(0.00702)	(0.00417)	(0.00267)		(0.00752)	(0.00487)
Leisure^2			-0.00162*				-0.00224**	
			(0.000932)				(0.00103)	
Leisure * alternative mobility				-0.00144***				-0.000702
				(0.000364)				(0.000617)
Library		0.0169***				0.00130		
		(0.00292)				(0.00247)		
Performing arts		0.00469***				0.00859***		
		(0.00112)				(0.00190)		
Cinema		0.00289***				0.00171		
		(0.000951)				(0.00122)		

Swimming pool			0.00113					0.000848		
			(0.00159)					(0.00141)		
Controls										
Gender: male	0.0164***	0.0156***	0.0150***	0.0157***	0.0154***	0.0129***	0.0126***	0.0122***	0.0125***	0.0125***
	(0.00167)	(0.00165)	(0.00164)	(0.00165)	(0.00164)	(0.00111)	(0.00118)	(0.00117)	(0.00117)	(0.00119)
Age 25 – 45	0.000168	0.000790	0.000937	0.00126	0.000992	0.00130	0.00150	0.00149	0.00188	0.00152
	(0.000905)	(0.000867)	(0.000858)	(0.000874)	(0.000856)	(0.00168)	(0.00159)	(0.00154)	(0.00151)	(0.00155)
Age 45 – 65	0.00700***	0.00668***	0.00683***	0.00689***	0.00671***	0.00592***	0.00590***	0.00599***	0.00590***	0.00587***
	(0.000817)	(0.000795)	(0.000785)	(0.000787)	(0.000781)	(0.00140)	(0.00133)	(0.00126)	(0.00126)	(0.00130)
Age > 65	0.00706***	0.00735***	0.00748***	0.00722***	0.00708***	0.00508***	0.00522***	0.00516***	0.00492***	0.00499***
	(0.000664)	(0.000617)	(0.000622)	(0.000628)	(0.000619)	(0.00112)	(0.00104)	(0.000995)	(0.000998)	(0.00103)
Western migration background	-0.00292***	-0.00334***	-0.00358***	-0.00321***	-0.00335***	-0.00777***	-0.00780***	-0.00765***	-0.00761***	-0.00771***
	(0.000696)	(0.000695)	(0.000694)	(0.000682)	(0.000686)	(0.00130)	(0.00130)	(0.00126)	(0.00124)	(0.00128)
Non-western migration background	-0.00493***	-0.00481***	-0.00457***	-0.00493***	-0.00486***	-0.00265***	-0.00269***	-0.00266***	-0.00279***	-0.00273***
	(0.000212)	(0.000208)	(0.000214)	(0.000210)	(0.000211)	(0.000268)	(0.000245)	(0.000240)	(0.000247)	(0.000243)
Household size	0.467***	0.443***	0.443***	0.431***	0.435***	0.345***	0.328***	0.328***	0.313***	0.324***
	(0.0145)	(0.0154)	(0.0155)	(0.0163)	(0.0157)	(0.0198)	(0.0182)	(0.0167)	(0.0181)	(0.0181)
Income per income recipient	0.00112**	0.00137***	0.00142***	0.00159***	0.00168***	0.00785***	0.00769***	0.00756***	0.00809***	0.00781***
	(0.000445)	(0.000437)	(0.000438)	(0.000442)	(0.000442)	(0.000541)	(0.000507)	(0.000504)	(0.000501)	(0.000498)
Number of income recipients	-7.08e-06***	-6.63e-06***	-6.13e-06***	-6.78e-06***	-5.98e-06***	-1.06e-05***	-9.87e-06***	-8.68e-06***	-9.60e-06***	-9.49e-06***
	(1.47e-06)	(1.42e-06)	(1.39e-06)	(1.42e-06)	(1.40e-06)	(1.68e-06)	(1.87e-06)	(1.99e-06)	(1.95e-06)	(1.89e-06)
Constant	-1.181***	-1.194***	-1.187***	-1.293***	-1.246***	-0.958***	-0.925***	-0.907***	-0.990***	-0.942***
	(0.107)	(0.101)	(0.101)	(0.104)	(0.0997)	(0.165)	(0.160)	(0.154)	(0.154)	(0.155)
Number of observations	3,876	3,876	3,876	3,876	3,876	10,496	10,496	10,496	10,496	10,496
R2	0.765	0.775	0.780	0.777	0.778	0.819	0.823	0.825	0.825	0.824
Controls	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Individual FE	*NO*	*NO*	*NO*	*NO*	*NO*	*YES*	*YES*	*YES*	*YES*	*YES*
Time FE	*NO*	*NO*	*NO*	*NO*	*NO*	*YES*	*YES*	*YES*	*YES*	*YES*
Outlier filters	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*

(Clustered) robust standard errors in parentheses: ***p<0.01, **p<0.05, *p<0.01

7.5 Sensitivity analysis

Table 7.8 Cross-sectional full regression results of the relationship between the distance to daily amenities and the number of cars per household, considering outlier filters, inclusion of population density, exclusion of shop for other daily groceries and combination of diminishing sensitivity and interaction with alternative mobility, respectively

	Cross-sectional											
	No outlier filters					Adding population density					No *other shop*	Combi
Distance to [..]	(1)	(2)	(3)	(2b)	(2c)	(1)	(2)	(3)	(2b)	(2c)	(3)	(2b/c)
Daily amenities	0.0176*** (0.00244)					0.0194*** (0.00272)						
Healthcare		0.0189*** (0.00309)		0.0410*** (0.0110)	0.0336*** (0.00588)		0.0137*** (0.00289)		0.0254** (0. 0114)	0.0136** (0.00611)		0.0339*** (0.0123)
Healthcare^2				-0.00476** (0.00222)					-0.00270 (0.00247)			-0.00372 (0.00280)
Healthcare * alternative mobility					-0.00135*** (0.000463)					0.000155 (0.000575)		0.000286 (0.000671)
General practice			0.0357*** (0.00900)					0.0113 (0.00773)			0.0203** (0.00818)	
Pharmacy			0.00790 (0.00619)					0.0107 (0.00753)			0.0202** (0.00811)	
Hospital			0.00491*** (0.00104)					0.00365*** (0.000970)			0.00512*** (0.00104)	
Retail		0.0229*** (0.00744)		0.0505** (0.0197)	0.0222 (0.0139)		0.00364 (0.00798)		0.0120 (0.0222)	-0.00357 (0.0119)		0.0431* (0.0239)
Retail^2				-0.0146** (0.00656)					-0.00472 (0.00942)			-0.0104 (0.00958)
Retail * alternative mobility					-0.000468 (0.00171)					0.000791 (0.00155)		-0.000443 (0.00160)
Large supermarket			0.0299** (0.0126)					0.0118 (0.0104)			0.0323*** (0.0103)	
Other shop for daily groceries			0.00414 (0.0125)					0.00535 (0.0115)				

Department store		-0.000980				-0.00514			-0.00291	
		(0.00287)				(0.00324)			(0.00343)	
Catering	0.00525		0.0859***	-0.00137	-0.0116		-0.0182	-0.0256*		0.0734**
	(0.00863)		(0.0258)	(0.0137)	(0.00853)		(0.0267)	(0.0143)		(0.0314)
Catering^2			-0.0454***				0.00210			-0.0430***
			(0.0112)				(0.0128)			(0.0136)
Catering * alternative mobility				4.35e-05				0.00180		4.61e-05
				(0.00150)				(0.00187)		(0.00191)
Cafes etc.		-0.00204				-0.00722*			-0.00882**	
		(0.00391)				(0.00382)			(0.00400)	
Cafeteria etc.		-0.0272**				-0.0242**			-0.0244**	
		(0.0129)				(0.0117)			(0.0115)	
Restaurant		-0.00125				0.00511			0.0139*	
		(0.00843)				(0.00733)			(0.00779)	
Children	0.0814***		0.129***	0.106***	0.0445***		0.0544*	0.0782***		0.160***
	(0.00990)		(0.0296)	(0.0179)	(0.00808)		(0.0305)	(0.0156)		(0.0331)
Children^2			-0.0280**				-0.00679			-0.0263
			(0.0140)				(0.0160)			(0.0165)
Children * alternative mobility				-0.00428**				-0.00519***		-0.00763***
				(0.00171)				(0.00183)		(0.00200)
Day care		0.0787***				0.0370***			0.0568***	
		(0.0160)				(0.0135)			(0.0146)	
School care		0.0158				0.00123			0.0126	
		(0.0127)				(0.0118)			(0.0130)	
Primary education		0.0217*				-0.00780			-0.000615	
		(0.0122)				(0.0108)			(0.0116)	
Secondary education		0.00685***				0.00996***			0.00694***	
		(0.00235)				(0.00247)			(0.00263)	
Alternative mobility	0.00106***		0.00226**	0.0105***	0.00147***		0.00612***	0.00631***		0.0116***
	(0.000404)		(0.00114)	(0.00194)	(0.000458)		(0.00180)	(0.00149)		(0.00214)
Alternative mobility^2			-1.62e-05				-0.000232***			-3.39e-05
			(3.48e-05)				(8.69e-05)			(9.58e-05)

Train station			0.00167*** (0.000526)					0.00261*** (0.000606)			0.00181*** (0.000647)	
Important transfer station			0.000223 (0.000204)					0.000158 (0.000256)			0.000438 (0.000272)	
Leisure		0.00653*** (0.00181)		0.0447*** (0.00693)	0.0219*** (0.00372)		0.0120*** (0.00178)		0.0212*** (0.00657)	0.0237*** (0.00390)		0.0252*** (0.00713)
Leisure^2				-0.00482*** (0.000831)					-0.00150* (0.000874)			-5.65e-05 (0.00106)
Leisure * alternative mobility					-0.00124*** (0.000265)					-0.00128*** (0.000338)		-0.00137*** (0.000398)
Library			0.0150*** (0.00314)					0.0127*** (0.00284)			0.0170*** (0.00290)	
Performing arts			0.00320*** (0.00101)					0.00397*** (0.00104)			0.00473*** (0.00112)	
Cinema			0.000779 (0.000666)					0.00274*** (0.000860)			0.00289*** (0.000950)	
Swimming pool			0.00245 (0.00176)					-0.000127 (0.00150)			0.00111 (0.00159)	
Controls												
Gender: male	0.0186*** (0.00190)	0.0172*** (0.00186)	0.0164*** (0.00182)	0.0173*** (0.00187)	0.0170*** (0.00185)	0.0115*** (0.00160)	0.0112*** (0.00160)	0.0112*** (0.00160)	0.0113*** (0.00161)	0.0111*** (0.00160)	0.0150*** (0.00163)	0.0154*** (0.00165)
Age 25 – 45	-0.00108 (0.000956)	-0.000425 (0.000917)	-0.000120 (0.000906)	0.000449 (0.000916)	-0.000138 (0.000908)	0.00230*** (0.000859)	0.00241*** (0.000843)	0.00241*** (0.000844)	0.00251*** (0.000845)	0.00247*** (0.000838)	0.000937 (0.000858)	0.00133 (0.000868)
Age 45 – 65	0.00574*** (0.000879)	0.00556*** (0.000843)	0.00573*** (0.000825)	0.00561*** (0.000822)	0.00546*** (0.000826)	0.00844*** (0.000742)	0.00818*** (0.000742)	0.00815*** (0.000743)	0.00817*** (0.000740)	0.00814*** (0.000737)	0.00683*** (0.000785)	0.00688*** (0.000779)
Age > 65	0.00671*** (0.000740)	0.00686*** (0.000701)	0.00710*** (0.000704)	0.00684*** (0.000693)	0.00666*** (0.000696)	0.00591*** (0.000617)	0.00601*** (0.000592)	0.00609*** (0.000605)	0.00591*** (0.000602)	0.00594*** (0.000595)	0.00748*** (0.000622)	0.00707*** (0.000630)
Western migration background	-0.00163 (0.00131)	-0.00182 (0.00123)	-0.00180 (0.00121)	-0.00169 (0.00121)	-0.00176 (0.00121)	-0.00207*** (0.000627)	-0.00236*** (0.000638)	-0.00267*** (0.000646)	-0.00232*** (0.000633)	-0.00249*** (0.000637)	-0.00358*** (0.000694)	-0.00326*** (0.000678)
Non-western migration background	-0.00536***	-0.00508***	-0.00484***	-0.00522***	-0.00508***	-0.00400***	-0.00388***	-0.00378***	-0.00393***	-0.00391***	-0.00457***	-0.00493***

	(0.000255)	(0.000244)	(0.000243)	(0.000243)	(0.000244)	(0.000204)	(0.000203)	(0.000210)	(0.000206)	(0.000206)	(0.000214)	(0.000213)
Household size	0.489***	0.457***	0.465***	0.438***	0.449***	0.452***	0.442***	0.437***	0.436***	0.437***	0.443***	0.428***
	(0.0165)	(0.0164)	(0.0166)	(0.0163)	(0.0163)	(0.0135)	(0.0144)	(0.0147)	(0.0151)	(0.0147)	(0.0155)	(0.0163)
Income per income recipient	0.000657	0.00110**	0.000999*	0.00149***	0.00145***	0.00121***	0.00142***	0.00149***	0.00150***	0.00161***	0.00142***	0.00179***
	(0.000572)	(0.000547)	(0.000557)	(0.000534)	(0.000549)	(0.000410)	(0.000410)	(0.000416)	(0.000415)	(0.000414)	(0.000438)	(0.000446)
Number of income recipients	-7.28e-06***	-6.04e-06***	-5.23e-06***	-6.17e-06***	-5.80e-06***	-2.44e-06**	-2.59e-06**	-2.90e-06**	-2.77e-06**	-2.28e-06*	-6.13e-06***	-6.11e-06***
	(1.37e-06)	(1.26e-06)	(1.21e-06)	(1.25e-06)	(1.24e-06)	(1.24e-06)	(1.25e-06)	(1.25e-06)	(1.26e-06)	(1.25e-06)	(1.39e-06)	(1.41e-06)
Population density						-1.86e-05***	-1.76e-05***	-1.73e-05***	-1.75e-05***	-1.72e-05***		
						(1.09e-06)	(1.03e-06)	(1.06e-06)	(1.03e-06)	(1.02e-06)		
Constant	-1.233***	-1.232***	-1.255***	-1.370***	-1.296***	-0.878***	-0.900***	-0.894***	-0.933***	-0.930***	-1.188***	-1.309***
	(0.128)	(0.122)	(0.121)	(0.123)	(0.122)	(0.102)	(0.0990)	(0.101)	(0.103)	(0.0989)	(0.101)	(0.103)
Number of observations	4,401	4,401	4,401	4,401	4,401	3,876	3,876	3,876	3,876	3,876	3,876	3,876
R2	0.725	0.737	0.744	0.745	0.742	0.799	0.803	0.805	0.804	0.804	0.780	0.779
Controls	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Individual FE	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
Time FE	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
Outlier filters	*NO*	*NO*	*NO*	*NO*	*NO*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*

(Clustered) robust standard errors in parentheses: ***p<0.01, **p<0.05, *p<0.01

Table 7.9 Panel full regression results of the relationship between the distance to daily amenities and the number of cars per household, considering outlier filters, inclusion of population density, exclusion of shop for other daily groceries and combination of diminishing sensitivity and interaction with alternative mobility, respectively

	Panel											
	No outlier filters					Adding population density					No *other shop*	Combi
Distance to [..]	(1)	(2)	(3)	(2b)	(2c)	(1)	(2)	(3)	(2b)	(2c)	(3)	(2b/c)
Daily amenities	0.0391***					0.0392***						
	(0.0102)					(0.00547)						
Healthcare		0.00665		0.0212	0.00973		0.00420		0.00538	0.00353		0.0102
		(0.00517)		(0.0149)	(0.00835)		(0.00475)		(0.0128)	(0.00724)		(0.0140)
Healthcare^2				-0.00345					-0.000286			-0.00246
				(0.00345)					(0.00349)			(0.00346)
Healthcare * alternative mobility					-0.000461					0.000123		0.000712
					(0.000682)					(0.000773)		(0.000799)
General practice			0.0198**					0.00947			0.0151**	
			(0.00803)					(0.00651)			(0.00697)	
Pharmacy			0.0203***					0.0194***			0.0259***	
			(0.00538)					(0.00589)			(0.00653)	
Hospital			-0.00137					-0.00134			-0.00191	
			(0.00152)					(0.00154)			(0.00159)	
Retail		0.0282***		0.0306*	0.0148		0.00993		-0.00300	0.00637		0.0155
		(0.00893)		(0.0161)	(0.0128)		(0.00620)		(0.0189)	(0.0115)		(0.0213)
Retail^2				-0.00343					0.00449			0.000234
				(0.00570)					(0.00755)			(0.00815)
Retail * alternative mobility					0.00222					0.000645		0.000342
					(0.00169)					(0.00188)		(0.00182)
Large supermarket			0.0196*					-0.000152			0.0140	
			(0.0106)					(0.00827)			(0.00894)	
Other shop for daily groceries			0.0152					0.0121				
			(0.00966)					(0.0104)				

Department store		0.00573**				0.00210			0.00564**	
		(0.00235)				(0.00201)			(0.00224)	
Catering	0.0283***		0.125***	0.0553***	0.0202**		0.0602***	0.0315**		0.140***
	(0.00817)		(0.0235)	(0.0124)	(0.00778)		(0.0211)	(0.0143)		(0.0263)
Catering²			-0.0524***				-0.0234**			-0.0520***
			(0.0119)				(0.00984)			(0.0112)
Catering * alternative mobility				-0.00435***				-0.00186		-0.00309
				(0.00145)				(0.00201)		(0.00203)
Cafes etc.		0.00906***				0.00720**			0.00939**	
		(0.00343)				(0.00364)			(0.00373)	
Cafeteria etc.		-0.00564				-0.00291			0.00356	
		(0.0102)				(0.0101)			(0.00918)	
Restaurant		-0.00480				-0.000593			0.00348	
		(0.00596)				(0.00528)			(0.00537)	
Children	0.0479***		0.107***	0.0643***	0.0323***		0.0515*	0.0440***		0.0873***
	(0.00991)		(0.0245)	(0.0152)	(0.00793)		(0.0265)	(0.0136)		(0.0288)
Children²			-0.0312***				-0.0109			-0.0181
			(0.0114)				(0.0142)			(0.0141)
Children * alternative mobility				-0.00261*				-0.00195		-0.00243
				(0.00154)				(0.00165)		(0.00175)
Day care		0.0111**				0.00632			0.00793	
		(0.00547)				(0.00499)			(0.00544)	
School care		0.00597				0.00324			0.00788	
		(0.00608)				(0.00534)			(0.00580)	
Primary education		0.0433***				0.0112			0.0226***	
		(0.0115)				(0.00707)			(0.00826)	
Secondary education		0.000282				0.00655**			0.00325	
		(0.00292)				(0.00256)			(0.00256)	
Alternative mobility	0.00111*		0.00101	0.00553**	0.00199**		0.00802***	0.00471**		0.0113***
	(0.000597)		(0.00154)	(0.00256)	(0.000815)		(0.00252)	(0.00205)		(0.00290)

Alternative mobility²			9.86e-07					-0.000358***			-0.000350***
			(4.65e-05)					(0.000133)			(0.000146)
Train station		-3.46e-05					0.00107			0.000658	
		(0.00123)					(0.00132)			(0.00140)	
Important transfer station		0.000574**					0.000672*			0.000867**	
		(0.000267)					(0.000362)			(0.000438)	
Leisure	0.00913***		0.0272***	0.0111***		0.00997***		0.0203***	0.0120***		0.0230***
	(0.00277)		(0.00770)	(0.00375)		(0.00251)		(0.00670)	(0.00428)		(0.00819)
Leisure²			-0.00269***					-0.00188**			-0.00205**
			(0.000886)					(0.000898)			(0.000969)
Leisure * alternative mobility				-0.000328					-0.000350		-0.000234
				(0.000292)					(0.000544)		(0.000563)
Library		0.00310					0.000183			0.00148	
		(0.00250)					(0.00257)			(0.00251)	
Performing arts		0.00795***					0.00671***			0.00880***	
		(0.00183)					(0.00173)			(0.00192)	
Cinema		0.00128					0.00169			0.00168	
		(0.00119)					(0.00112)			(0.00123)	
Swimming pool		0.00100					0.000934			0.000784	
		(0.00150)					(0.00133)			(0.00140)	
Controls											
Gender: male	0.0140***	0.0133***	0.0128***	0.0131***	0.0132***	0.00978***	0.00968***	0.00957***	0.00974***	0.00967***	0.0122***	0.0125***
	(0.00161)	(0.00157)	(0.00150)	(0.00158)	(0.00157)	(0.00124)	(0.00130)	(0.00130)	(0.00131)	(0.00131)	(0.00117)	(0.00118)
Age 25 – 45	0.000617	0.000892	0.000977	0.00142	0.000923	0.00245*	0.00247**	0.00240*	0.00260**	0.00247**	0.00148	0.00186
	(0.00197)	(0.00177)	(0.00165)	(0.00160)	(0.00171)	(0.00127)	(0.00124)	(0.00122)	(0.00122)	(0.00122)	(0.00155)	(0.00150)
Age 45 – 65	0.00590***	0.00590***	0.00612***	0.00591***	0.00584***	0.00663***	0.00657***	0.00657***	0.00653***	0.00654***	0.00597***	0.00589***
	(0.00172)	(0.00160)	(0.00147)	(0.00149)	(0.00156)	(0.00106)	(0.00103)	(0.00100)	(0.000998)	(0.00102)	(0.00127)	(0.00124)

Age > 65	0.00495***	0.00497***	0.00494***	0.00482***	0.00482***	0.00419***	0.00428***	0.00427***	0.00413***	0.00419***	0.00516***	0.00483***
	(0.00107)	(0.000951)	(0.000890)	(0.000919)	(0.000945)	(0.000937)	(0.000890)	(0.000877)	(0.000874)	(0.000890)	(0.00100)	(0.000998)
Western migration background	-0.00397*	-0.00415*	-0.00397*	-0.00411*	-0.00412*	-0.00598***	-0.00608***	-0.00612***	-0.00603***	-0.00608***	-0.00762***	-0.00759***
	(0.00232)	(0.00219)	(0.00214)	(0.00215)	(0.00217)	(0.00110)	(0.00112)	(0.00110)	(0.00108)	(0.00111)	(0.00125)	(0.00124)
Non-western migration background	-0.00304***	-0.00296***	-0.00290***	-0.00308***	-0.00300***	-0.00247***	-0.00250***	-0.00247***	-0.00254***	-0.00252***	-0.00266***	-0.00281***
	(0.000232)	(0.000219)	(0.000222)	(0.000230)	(0.000219)	(0.000241)	(0.000230)	(0.000233)	(0.000233)	(0.000230)	(0.000240)	(0.000245)
Household size	0.370***	0.340***	0.343***	0.326***	0.337***	0.347***	0.337***	0.334***	0.329***	0.335***	0.328***	0.313***
	(0.0194)	(0.0175)	(0.0156)	(0.0182)	(0.0174)	(0.0160)	(0.0150)	(0.0141)	(0.0149)	(0.0151)	(0.0168)	(0.0179)
Income per income recipient	0.00635***	0.00647***	0.00621***	0.00675***	0.00656***	0.00659***	0.00656***	0.00659***	0.00683***	0.00664***	0.00756***	0.00810***
	(0.000865)	(0.000780)	(0.000790)	(0.000761)	(0.000771)	(0.000473)	(0.000456)	(0.000443)	(0.000461)	(0.000455)	(0.000504)	(0.000499)
Number of income recipients	-8.40e-06***	-7.43e-06***	-6.16e-06**	-7.27e-06***	-7.23e-06***	-4.09e-06***	-3.89e-06**	-3.65e-06**	-4.00e-06**	-3.81e-06**	-8.69e-06***	-9.36e-06***
	(2.32e-06)	(2.60e-06)	(2.67e-06)	(2.66e-06)	(2.64e-06)	(1.47e-06)	(1.59e-06)	(1.67e-06)	(1.65e-06)	(1.60e-06)	(1.99e-06)	(1.96e-06)
Population density						-1.45e-05***	-1.38e-05***	-1.33e-05***	-1.33e-05***	-1.36e-05***		
						(1.15e-06)	(1.13e-06)	(1.18e-06)	(1.11e-06)	(1.12e-06)		
Constant	-1.016***	-0.971***	-0.965***	-1.042***	-0.985***	-0.723***	-0.711***	-0.700***	-0.748***	-0.723***	-0.909***	-0.993***
	(0.146)	(0.138)	(0.131)	(0.127)	(0.132)	(0.151)	(0.147)	(0.145)	(0.148)	(0.145)	(0.154)	(0.152)
Number of observations	11,627	11,627	11,627	11,627	11,627	10,496	10,496	10,496	10,496	10,496	10,496	10,496
R2	0.787	0.793	0.797	0.796	0.794	0.835	0.836	0.837	0.837	0.836	0.825	0.825
Controls	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Individual FE	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Time FE	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Outlier filters	*NO*	*NO*	*NO*	*NO*	*NO*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*

(Clustered) robust standard errors in parentheses: ***p<0.01, **p<0.05, *p<0.01

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