Daily travel behaviour amongst residents in the north of the Netherlands

Assessing the effect of sociodemographic, psychosocial, and built environment factors

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Abstract

Private car use produces a number of negative externalities, such as climate change, physical inactivity, and air pollution. Therefore, a shift towards sustainable mobility is needed. A well-developed understanding of daily travel behaviour could help design effective policy measures to foster walking, cycling, and the use of public transport. The effects of built environment factors, sociodemographic factors, and psychosocial factors on daily travel behaviour have been studied extensively. However, daily travel behaviour has barely been studied in the Netherlands, let alone the north of the Netherlands. Therefore, the aim of this study was to assess the effect of built environment factors, sociodemographic factors, and psychosocial factors to explain daily travel behaviour amongst adults in the north of the Netherlands.

An online map-based survey tool was distributed to collect relevant (geographical) data. Complemented by secondary datasets, factor analysis and multivariate linear regression analysis were used to analyse the collected data (N=192). Sociodemographic factors, psychosocial factors (i.e. travel attitudes, perceived behavioural control, and neighbourhood preferences), and some of the built environment factors (i.e. five Ds) were found to be related to both monthly car driving distance and monthly active travel distance, albeit to different extents. In line with previous studies, built environment factors only seemed to play a minor role in explaining daily travel behaviour. It was also found that it is important to take into account trip purpose when studying daily travel behaviour. This thesis concludes with a number of policy recommendations and a reflection and research agenda.

Key words: travel behaviour; travel attitudes; perceived behavioural control; neighbourhood preferences; built environment

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List of abbreviations

CBS	Central Bureau for Statistics
GHG	Greenhouse Gas
GIS	Geographic Information System
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
NP	Neighbourhood Preference
PBC	Perceived Behavioural Control
PPGIS	Public Participation Geographic Information System
SDG	Sustainable Development Goal
TA	Travel Attitude
TPB	Theory of Planned Behaviour
UN	United Nations
VMT	Vehicle Miles Travelled

1. Introduction

1.1. Societal relevance

According to the International Energy Agency, the transport sector is rather energy intensive, while still being heavily reliant on oil (IEA, 2021). Therefore, the amount of greenhouse gas (GHG) emissions from the transport sector is substantial. In the Netherlands 19 percent of the total amount of GHG emissions can be attributed to the transport sector, excluding aviation (Figure 1). Around half of these emissions originate from passenger cars, which were responsible for 17,8 megatons of carbon dioxide equivalent in 2019 (CBS, 2021a). Given these statistics, private car use plays a substantial role in accelerating climate change (Douglas et al., 2011), which has predominantly negative consequences for both human civilisations and ecosystems (IPCC, 2014).

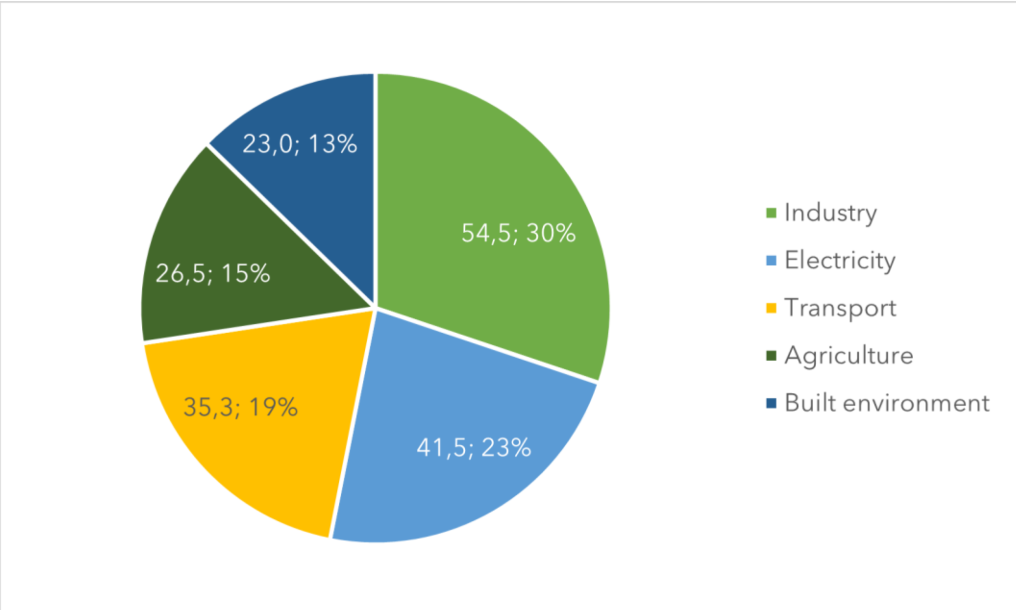

Figure 1
GHG emissions (megatonnes CO2 equivalent) per sector in 2019 in the Netherlands.
Based on: CBS (2021a).

Next to its considerable impact on climate change, automobility is also associated with physical inactivity and obesity (Douglas et al., 2011). To illustrate, Frank et al. (2004) found that the likelihood of obesity increased by 6 percent for each additional hour spent per day in a car, while the probability of obesity decreased by 4,8 percent for each additional kilometre walked per day (ibid). In addition to physical health concerns, physical inactivity is linked to mental health issues as well (Galper et al., 2006).

Private car use also produces other negative externalities, such as air and noise pollution (Chatziioannou et al., 2020). According to previous studies, these can have a negative impact on physical and mental health as well (Manisalidis et al., 2020; Passchier-Vermeer & Passchier, 2000; Peris, 2020). Air and noise pollution also have a negative impact on the environment. Air pollution contributes to acid rain and eutrophication (Manisalidis et al., 2020), while noise pollution is related to physiological and behavioural changes in certain species, resulting in lower population densities (Peris, 2020).

In the light of these negative externalities, which affect both people and nature, Banister (2008) introduced the sustainable mobility paradigm. This paradigm insists that the number of trips should be reduced; modal shifts towards walking, cycling, and public transport should be encouraged; trip distances should be reduced; and greater efficiency in the transport system should be encouraged (ibid). According to the United Nations, sustainable mobility plays a key role in achieving the Paris Agreement and a number of Sustainable Development Goals (SDGs), including SDG 3 (Good health and wellbeing) and SDG 11 (Sustainable cities and communities; UN, 2021).

Despite extensive research about the effects of built environment factors (e.g. Ewing & Cervero, 2010), sociodemographic factors (e.g. Prillwitz & Barr, 2011), and psychosocial factors (e.g. Eriksson & Forward, 2011) on daily travel behaviour, encouraging sustainable mobility remains a challenge (Pronello & Gaborieau, 2018)[1]. Nonetheless, a better understanding of travel behaviour could logically help design effective policy measures to reduce the number of trips; induce modal shifts towards walking, cycling, and public transport; and reduce trip distances.

1.2. Academic relevance and research gap

The role of built environment factors, sociodemographic factors, and psychosocial factors in explaining travel behaviour has been studied quite extensively. To illustrate, Ewing & Cervero (2010) conducted a meta-analysis of more than fifty studies (e.g. Cervero & Kockelman, 1997) concerning the relationship between built environment factors and travel behaviour, while Pronello & Gaborieau (2018) reviewed the current body of academic literature (e.g. Anable, 2005) regarding the association between psychosocial factors and travel behaviour. Some studies even assessed the effects of built environment factors, sociodemographic factors, and psychosocial factors on travel behaviour simultaneously (e.g. Ramezani et al., 2018a; 2018b).

[1] The concept of travel behaviour is used in this study to refer to daily travel behaviour (as opposed to holiday travel behaviour).

Despite the wealth of international studies about daily travel behaviour, there are only a couple of peer-reviewed journal articles that concern travel behaviour in the Netherlands (e.g. Meurs & Haaijer, 2001; Ettema & Nieuwenhuis, 2017). Unfortunately, Meurs & Haaijer (2001) did not take into account the effect of psychosocial factors on travel behaviour, while these have been found to play an important role in explaining travel behaviour (Hunecke et al., 2010). Ettema & Nieuwenhuis (2017) did take into account the effect of psychosocial factors (i.e. travel attitudes), but the effect of built environment factors was not explicitly addressed, while these seem to relate to travel behaviour as well (Ewing & Cervero, 2010).

Next to these peer-reviewed journal articles, there is also some grey literature regarding travel behaviour in the Netherlands (e.g. Snellen et al., 2005). While Snellen et al. (2005) included built environment factors and sociodemographic factors in their analyses, psychosocial factors had unfortunately not been taken into account. Thus, there does not seem to be any study that combines built environment factors, sociodemographic factors, and psychosocial factors to explain travel behaviour in the Netherlands, although travel behaviour might be affected by these factors simultaneously (Cao et al., 2009; Cervero & Kockelman, 1997; Guan et al., 2020; Ramezani et al., 2018a; 2018b; 2020).

Furthermore, a study concerning explanations for travel behaviour in the north of the Netherlands does not seem to exist at all. Although the Central Bureau for Statistics (CBS) is continuously monitoring travel behaviour per region in the Netherlands, including the north of the Netherlands, this hardly tells anything about the factors explaining it. More details about this monitoring programme are provided in Chapter 2. A mobility monitoring report concerning travel behaviour in the Groningen-Assen region (CBS Urban Data Center Regio Groningen, 2020) also did not go beyond descriptive statistics and therefore did not provide any insight into the factors underlying travel behaviour.

1.3. Research aim and research questions

As a better understanding of travel behaviour may help policy makers encourage sustainable mobility, this study aimed to address the aforementioned research gap. More specifically, the aim of this study was to assess the effect of built environment factors, sociodemographic factors, and psychosocial factors to explain daily travel behaviour amongst adults in the north of the Netherlands. In order to achieve this study aim, the primary research question was defined as follows:

What is the effect of built environment factors, sociodemographic factors, and psychosocial factors on daily travel behaviour amongst adults in the north of the Netherlands?

Daily travel behaviour was operationalised as 'monthly car driving distance' and 'monthly walking and cycling distance'. The latter is also referred to as 'monthly active travel distance' throughout the thesis. Monthly distance travelled by car (as passenger) and monthly distance travelled by public transport have not been taken into account due to the limited number of respondents that travelled by these modes of transport. More details about operationalisation are provided in Chapter 3. The importance of built environment factors, sociodemographic factors, and psychosocial factors in explaining travel behaviour might not be the same for each trip purpose (Meurs & Haaijer, 2001), which has also been considered. Consequently, the secondary research questions were defined as follows:

1. What built environment factors influence monthly car driving distance and monthly active travel distance?
2. What sociodemographic factors influence monthly car driving distance and monthly active travel distance?
3. What psychosocial factors influence monthly car driving distance and monthly active travel distance?
4. Are monthly car driving distance and monthly active travel distance influenced by different factors for different trip purposes?

Note that the secondary research questions, like the main research question, all concern adults (>18 years old) in the north of the Netherlands. This region consists of the three northern provinces, i.e. Drenthe, Friesland, and Groningen (Figure 4). More details about the study area are provided in Chapter 3.

1.4. Reading guide

This thesis is organised as follows: Chapter 2 provides an overview and discussion of the current body of academic literature concerning travel behaviour and its determinants. Based on this literature review, a conceptual model is presented to structure data collection and data analysis. Methods for data collection and data analysis are elaborated upon in Chapter 3 and the results are presented and compared with previous studies in Chapter 4. A summary of the research findings, implications for planning practice, and a reflection and research agenda are provided in Chapter 5.

2. Theoretical framework

2.1. Introducing the concept of travel behaviour

The concept 'travel behaviour' plays a central role in this study. However, a clear definition of the concept is hard to find in the literature. Apparently, it is often taken for granted what is meant with 'travel behaviour', which could potentially lead to misunderstandings about the concept. Based on Handy et al. (2002) and Tillema & Jorritsma (2016), this study perceives the concept 'travel behaviour' as a collective name for a number of choices and actions relating to travel. These include the number of trips, trip distance, modal choice, and trip purpose (e.g. working, shopping). Figure 2 illustrates this understanding of travel behaviour. Table 1 provides an overview of the different elements of travel behaviour that have been addressed in a selection of the reviewed studies.

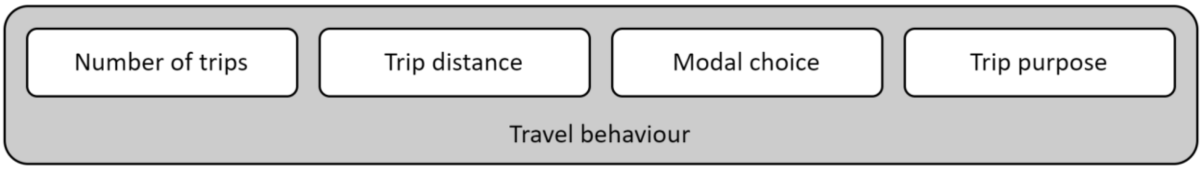

Figure 2
Conceptualisation of travel behaviour.
Based on: Handy et al. (2002) and Tillema & Jorritsma (2016).

Table 1
Elements of travel behaviour addressed in a selection of the reviewed studies.

Study	Researched element(s) of travel behaviour
Anable (2005)	Aggregate trip distance (Vehicle Miles Travelled (VMT)) Number of trips Modal choice (car, alternative to car)
Bamberg et al. (2003)	Modal choice (public transport)
Bamberg & Schmidt (2003)	Modal choice (car)
Dill et al. (2014)	Number of trips Modal choice (bicycle, walking)
Eriksson & Forward (2011)	Modal choice (car, bus, bicycle)
Ewing & Cervero (2010)	Aggregate trip distance (VMT) Number/probability of trips Modal choice (car, public transport, walking)
Kuppam et al. (1999)	Modal choice (car, public transport, non-motorised)
Prillwitz & Barr (2011)	Trip purpose (work, shopping, leisure, visiting friends and family) Modal choice (car/motorbike, public transport, bicycle, walking)
Ramezani et al. (2018a; 2018b)	Number of trips Trip purpose (work, non-work) Modal choice (car, public transport, bicycle, walking)
Stevens (2017)	Aggregate trip distance (VMT) Modal choice (car)
Wall et al. (2007)	Modal choice (car)
Zailani et al. (2016)	Trip purpose (work/study, shopping, leisure) Modal choice (public transport)

In the Netherlands travel behaviour is continuously being monitored by the Central Bureau for Statistics (CBS) by means of questionnaire surveys. Researched variables include number of trips, trip distance, modal choice, trip purpose, and travel time. Based on this, travel behaviour can be described quite extensively on an aggregate level (CBS, 2021b). Travel behaviour can also be summarised by region, such as the north of the Netherlands (Table 5). These aggregated data provide valuable insights into travel behaviour amongst residents in the north of the Netherlands. However, they hardly tell anything about the relationships between travel behaviour on the one hand and built environment factors, sociodemographic factors, and psychosocial factors on the other hand.

This chapter provides an overview of the current academic debate concerning the relationship between built environment factors and travel behaviour (section 2.2.), sociodemographic factors and travel behaviour (section 2.3.), and psychosocial factors and travel behaviour (section 2.4.). Based on this literature review, an integrated conceptual model has been developed, which is discussed in section 2.5.

2.2. Built environment factors explaining travel behaviour

From a utilitarian perspective, travel is perceived as a derived demand. This means that the demand for travel is derived from desires of people to participate in activities at different locations. Activities include living, working, studying, shopping, and recreating (Handy et al., 2002; Van Wee, 2002; Van Wee et al., 2003). To illustrate this perspective on travel, imagine an individual that lives at location A. This individual has the desire to participate in activity X at location B. In order for this individual to meet his/her desire to participate in activity X, he/she needs to travel from location A to location B. Following the example, the demand to travel from location A to location B is derived from the desire to participate in activity X.

According to the utilitarian perspective on travel, the spatial environment plays a role in explaining travel behaviour (Van Wee, 2002; Van Wee et al., 2003). After all, the spatial environment accommodates activities at different locations, as illustrated by the example in the previous paragraph. Besides, the spatial environment also accommodates travel between these locations by means of infrastructure. In line with this perspective on the spatial environment, Van Acker et al. (2010) argue that the spatial environment provides a context for lifestyle behaviour, locational behaviour, and activity behaviour, which are believed to affect travel behaviour either directly (activity behaviour) or indirectly (locational and lifestyle behaviour). The belief that the spatial environment affects travel behaviour is also endorsed by Banister (2008), since he advocates land use policy measures to promote walking and cycling.

Many studies concerning the relationship between the spatial environment and travel behaviour have focussed on the association between the built environment and travel behaviour (Ewing & Cervero, 2010). According to Handy et al. (2002), the built environment is a collective name for land use patterns, the transportation system, and urban design. As such, the built environment can be considered as a multidimensional concept, which should be operationalised by means of different factors.

In one of the most cited articles concerning the relationship between the built environment and travel behaviour, Cervero & Kockelman (1997) identified the so-called three Ds: density, diversity, and design. Regarding density, a distinction was made between intensity and accessibility, while the latter variable was considered a separate factor in other studies (Ewing & Cervero, 2001; 2010). Based on a literature review, Handy et al. (2002) also endorsed density, diversity, and design as relevant built environment factors for studying travel behaviour, although they did not all label them as such. To illustrate, 'land use mix' was used by Handy et al. (2002) to refer to diversity, while 'street connectivity', 'street scale', and 'aesthetic qualities' all relate to design. In their meta-analysis of studies about the association between the built environment and travel behaviour, Ewing & Cervero (2010) added destination accessibility and distance to transit to the three Ds. As such, Ewing & Cervero (2010) introduced the five Ds: density, diversity, design, destination accessibility, and distance to transit (Zhang et al., 2014).

Table 2 is an overview of different built environment factors that have been studied in relation to travel behaviour. Note that these factors are not mutually exclusive and that they can correlate with each other (Ewing & Cervero, 2010; Handy et al., 2002). Besides, there can be different indicators of the same built environment factor (Ewing & Cervero, 2010).

Table 2
Built environment factors studied in relation to travel behaviour.
Based on: Cervero & Kockelman (1997), Ewing & Cervero (2001; 2010), and Handy et al. (2002).

Built environment factor	Explanation	Examples of indicators
Density	The amount of a variable of interest in a given area relative to the size of the area.	Population density Job density
Diversity	The proximity or number of different land uses in a certain area.	Distance to retail Land use mix
Design	Characteristics of the street network and appearance of public space.	Intersection density Presence of street canopy
Destination accessibility	The ease of access to activities.	Job accessibility
Distance to transit	The proximity of public transport services.	Distance to nearest train station

2.2.1. Associations between built environment factors and travel behaviour

Table 3 is an overview of the findings of the literature that has been reviewed for the current study. It only concerns literature that used built environment factors to explain travel behaviour. For each built environment factor it is indicated whether it plays a significant role in explaining travel behaviour. Most studies from before 2010 have already been analysed by Ewing & Cervero (2010), whose findings are summarised in the table. Two Dutch studies have not been considered by Ewing & Cervero (2010), which is why the findings of Meurs & Haaijer (2001) and Snellen et al. (2005) are included in Table 3 as well.

Table 3
Reviewed literature concerning the association between built environment factors and travel behaviour.

Study	N	Sample location	Researched mode of transport	Density	Diversity	Design	Destination accessibility	Distance to transit
Dill et al. (2014)	1159	Portland, Oregon (US)	Walking	-	-	Yes	Yes	-
			Bicycle	-	-	Yes	Yes	-
Ewing & Cervero (2010)	Approx. 60 studies	-	Car	No	Yes	Yes	Yes	No
			Public transport	No	Yes	Yes	No	Yes
			Walking	No	Yes	Yes	Yes	Yes
Meurs & Haaijer (2001)	713	The Netherlands	Car	Partly	-	No	Yes	-
			Public transport	No	-	No	Yes	-
			Walking	No	-	No	Yes	-
			Bicycle	No	-	No	Yes	-
Ramezani et al. (2018a)	248	San Francisco, California (US)	Sustainable modes of transport*	Yes	Maybe	Yes	-	-
Ramezani et al. (2018b)	524	Rome (Italy)	Sustainable modes of transport*	Yes	Maybe	Yes	-	-
Snellen et al. (2005)	> 10k	The Netherlands	Car	-	Yes	-	Yes	Yes
			Public transport	-	Yes	-	Yes	Yes
			Active transport	-	Yes	-	Yes	No
Stevens (2017)	37 studies	-	Car	Yes	Yes	Yes	Yes	No

* Walking, bicycle, and public transport are considered sustainable modes of transport.

In their meta-analysis of studies concerning the relationship between the built environment and travel behaviour, Ewing & Cervero (2010) made a distinction between vehicle miles travelled, probability of walking trips, and probability of transit trips. Contrary to what is commonly assumed (Van Wee, 2002), population density and job density were hardly associated with either operationalisation of travel behaviour. Other built environment factors that usually coincide with high densities explained travel behaviour to a greater extent than did density (Ewing & Cervero, 2010). For instance, destination accessibility was relatively strongly related to both vehicle miles travelled (negative) and the probability of walking (positive), while a lower distance to transit was related to a higher probability of transit trips. Besides, design was especially associated with the probability of walking trips and transit trips (ibid).

Based on more recent studies, Stevens (2017) replicated the meta-analysis by Ewing & Cervero (2010), but focussed on vehicle miles travelled only. It was found that destination accessibility was negatively related to vehicle miles travelled (Stevens, 2017), which is in line with the findings of Ewing & Cervero (2010). In contrast to the findings of Ewing & Cervero (2010), the (negative) effect of population density on vehicle miles travelled was relatively large compared to other built environment factors, such as diversity and distance to transit (Stevens, 2017).

Dill et al. (2014) studied walking and cycling behaviour amongst residents living in Portland, Oregon (US). In accordance with the findings of Ewing & Cervero (2010), Dill et al. (2014) found that neighbourhood design helped to explain the number of walking and cycling trips in the past month. Next to that, destination accessibility was positively related to the number of walking and cycling trips in the past month. As Dill et al. (2014) distinguished between direct and indirect effects, they found that the effect of design and destination accessibility on walking and cycling behaviour was almost completely, if not completely, mediated by psychosocial factors (see section 2.4.).

Based on empirical research in San Francisco, California (US) and Rome (Italy), Ramezani et al. (2018a; 2018b) found that neighbourhood design played a role in explaining modal choice for work and non-work trips, which is largely in line with the findings of previous studies (e.g. Ewing & Cervero, 2010). Interestingly, it was found that population density did not have a consistent effect on modal choice. More specifically, population density was positively associated with walking, cycling, and the use of public transport in San Francisco, while the relationship was neutral for work trips and even negative for non-work trips in Rome (Ramezani et al., 2018a). This finding implies that the effect of built environment factors on travel behaviour depends on trip purpose and can differ across geographical contexts. Next to the effect of design and density on travel behaviour, it seems plausible that diversity is positively related to walking, cycling, and the use of public transport, although this assumption could not be verified due to methodological limitations (Ramezani et al., 2018a; 2018b).

Meurs & Haaijer (2001) studied travel behaviour in the Netherlands, although the region had not been specified. In accordance with the findings of Stevens (2017), it was found that the number of car trips was negatively related to (address) density. However, the relationship was not statistically significant anymore after third variables, such as sociodemographic factors, had been accounted for (Meurs & Haaijer, 2001). It is striking that Meurs & Haaijer (2001) did not find any statistically significant relationship between neighbourhood design and the number of trips for each of the studied modes of transport (i.e. car, public transport, bicycle, and walking). The difference with other studies (e.g. Ewing & Cervero, 2010) might be due to the use of different neighbourhood design indicators and differences in geographical context. Although destination accessibly was found to be related to the number of trips for each of the studied modes of transport, the direction of the relationship depended on the operationalisation of the concept (Meurs & Haaijer, 2001).

Based on a large secondary dataset obtained from a monitoring programme by the Central Bureau for Statistics (CBS), Snellen et al. (2005) found that diversity affected travel distances by each of the studied modes of transport (i.e. car, public transport, and active transport). In line with Ewing & Cervero (2010), diversity is negatively related to travel distance by car. However, the effect of diversity on distance travelled by public transport and distance travelled by active transportation modes depends on the operationalisation of the concept (Snellen et al., 2005). In accordance with previously discussed studies (e.g. Stevens, 2017), destination accessibility was found to be negatively associated with distance travelled by car (Snellen et al., 2005). The opposite was true for distance travelled by active transportation modes (ibid), which is also in line with studies discussed before (e.g. Dill et al., 2014). It was found that distance to a train station was positively related to distance travelled by car, but negatively associated with distance travelled by public transport (Snellen et al., 2005). The latter is also supported by the findings of Ewing & Cervero (2010).

Thus, there is ample evidence that a number of built environment factors are associated with travel behaviour (e.g. Ewing & Cervero, 2010; Dill et al., 2014; Ramezani et al., 2018a; 2018b; Stevens, 2017). However, the importance of built environment factors in explaining the number of trips seems to differ per trip purpose and mode of transport (Meurs & Haaijer, 2001). Besides, it must be noted that the effect of one single built environment factor on travel behaviour is rather small. Nonetheless, it is assumed that the combined effect of multiple built environment factors on travel behaviour can be substantial (Cervero & Kockelman, 1997; Ewing & Cervero, 2010; Ramezani et al., 2018a).

2.2.2. Accounting for residential self-selection

Although certain built environment factors seem to be related to travel behaviour, it does not necessarily mean that the relationship between the built environment and travel behaviour is a causal one. It has been found that residential self-selection obscures the potentially causal relationship between built environment factors and travel behaviour (Cao et al., 2009; Ewing & Cervero, 2010; Guan et al., 2020; Van Acker et al., 2010). Residential self-selection refers to the tendency of individuals to choose a residential location that is consistent with their attitudes towards and preferences for travel (Cao et al., 2009; Ettema & Nieuwenhuis, 2017; Van Acker et al., 2010).

Cao et al. (2009) conducted a literature review of 38 studies (e.g. Bagley & Mokhtarian, 2002; Kitamura et al., 1997) concerning residential self-selection. Although the effect of the built environment on travel behaviour decreased substantially after controlling for residential self-selection, the built environment still had an autonomous effect on travel behaviour. It was expected that the autonomous effect of the built environment on travel behaviour was rather small compared to the effects of sociodemographic and other variables, however (Cao et al., 2009). Based on more recent studies concerning residential self-selection, Guan et al. (2020) also conducted a literature review. In accordance with the findings of Cao et al. (2009), it was found that the built environment still had an autonomous effect on travel behaviour after controlling for residential self-selection. The magnitude of the autonomous effect of the built environment on travel behaviour still remained an open question, however (Guan et al., 2020).

Failing to account for residential self-selection may lead to either an under- or overestimation of the effect of the built environment on travel behaviour, depending on sample characteristics (Guan et al., 2020). According to Cao et al. (2009), the autonomous effect of the built environment on travel behaviour might be overestimated if residential self-selection has not been accounted for. It is to be expected that this statement is valid if a majority of the sample population lives in a neighbourhood congruent with its neighbourhood preferences (i.e. residential consonants; Guan et al., 2020). In contrast, there is also evidence that suggests not accounting for residential self-selection might lead to an underestimation of the autonomous effect of the built environment on travel behaviour (Ewing & Cervero, 2010; Stevens, 2017). It is to be expected that this statement is valid if a majority of the sample population lives in a neighbourhood dissonant with its neighbourhood preferences (i.e. residential dissonants; Guan et al., 2020).

Ramezani et al. (2020) analysed a sample of 474 residents living in or near Turku (Finland) and they found that there were significant differences in travel behaviour across four clusters of travellers based on travel attitudes and neighbourhood preferences, which implies that travel attitudes and neighbourhood preferences are related to travel behaviour. Consequently, an association between residential location (i.e. the built environment) and travel behaviour might result from travel attitudes and neighbourhood preferences, rather than from the built environment itself (Cao et al., 2009; Schwanen & Mokhtarian, 2005). Therefore, both travel attitudes and neighbourhood preferences need to be taken into account, in order to accurately establish the autonomous effect of the built environment on travel behaviour (Ramezani et al., 2018b; Schwanen & Mokhtarian, 2005).

2.3. Sociodemographic factors explaining travel behaviour

From a utilitarian perspective, an individual is believed to choose the travel alternative to which he/she ascribes highest utility (Golob et al., 1980). It is important to note that the utility ascribed to a particular travel alternative is highly subjective and it is assumed that it is linked to a traveller's sociodemographic characteristics, such as gender and age. In other words, travel behaviour is considered to correlate with sociodemographics (Anable, 2005). In line with this, Domarchi et al. (2008) state that studies based on the utilitarian perspective assume that modal choice is an outcome of a traveller's sociodemographic characteristics and attributes of a travel alternative, such as costs, time, and comfort.

Indeed, sociodemographic factors likely play a role in explaining travel behaviour (Dill et al., 2014; Kuppam et al., 1999; Prillwitz & Barr, 2011; Ramezani et al., 2018a; 2018b). Based on a sample (N=1561) in the United Kingdom, Prillwitz & Barr (2011) clustered travellers in four distinct groups (i.e. segments) with regard to self-reported travel behaviour. It was found that there were significant differences in sociodemographic characteristics across the four travel behaviour based segments. These sociodemographic characteristics included age, gender, income, and number of children in the household.

As explained in the previous section, Dill et al. (2014) studied walking and cycling behaviour amongst 1159 residents living in Portland, Oregon (US). In line with the findings of Prillwitz & Barr (2011), it was found that sociodemographic characteristics were important predictors of the number of walking trips and the number of cycling trips, albeit indirectly via a number of psychological constructs. The sociodemographic characteristics included age, gender, education, and the number of vehicles in the household.

On the basis of an analysis of a US transportation panel survey (N≈1700), Kuppam et al. (1999) found that sociodemographic characteristics also played an important role in explaining modal choice amongst commuters. More specifically, age, income, household type, number of vehicles per adult, and employment status were found to be related to modal choice for commuting trips.

As mentioned in the previous section, Ramezani et al. (2018a; 2018b) did empirical research in San Francisco, California (US) and Rome (Italy). In line with previous studies, it was found that sociodemographic characteristics played a role in explaining modal choice for work and non-work trips. In addition to relatively conventional sociodemographic characteristics, such as income and age, the number of bikes in a household, whether an individual is disabled and whether an individual owns a public transport card were found to be related with modal choice as well.

Although the importance of sociodemographic factors in explaining the number of trips differs per trip purpose and mode of transport (Meurs & Haaijer, 2001), it has been argued that psychosocial factors need to be considered as well, in order to properly understand travel behaviour (Hunecke et al., 2010). In the light of this, Kuppam et al. (1999) compared a number of models explaining modal choice amongst commuters: model 1 included exclusively sociodemographic variables and model 2 included exclusively attitudinal variables. It was found that model 2 (attitudinal) performed better than model 1 (sociodemographic) with regard to explaining modal choice amongst commuters. In line with this, Dill et al. (2014) found that psychosocial factors were more important determinants of walking and cycling behaviour than sociodemographic characteristics.

2.4. Theory of Planned Behaviour explaining travel behaviour

Many studies refer to the Theory of Planned Behaviour (TPB) to explain travel behaviour from a psychosocial perspective (Gardner & Abraham, 2008; Hunecke et al., 2010; Pronello & Gaborieau, 2018). The TPB assumes that behaviour results from a process of deliberate reasoning (Ajzen, 1991). According to this theory, whether an individual performs a certain behaviour depends on an individual's intention to perform that behaviour (i.e. behavioural intention). More interesting, however, are the factors that explain behavioural intention: attitudes, subjective norms, and perceived behavioural control.

Attitude refers to the degree to which an individual has a positive or negative evaluation of a certain behaviour, subjective norm is the perceived social pressure with regard to performing a certain behaviour, and perceived behavioural control refers to the perceived ability to perform a certain behaviour (Ajzen, 1991). As such, the TPB explains that attitudes do not necessarily translate into behaviour consistent with these attitudes, a phenomenon also referred to as attitude-action gap, attitude-behaviour gap, or value-action gap (Kollmuss & Agyeman, 2002). For example, a person with strong anti-car attitudes might still take the car when alternatives are too expensive, too slow, and/or not even available, i.e. when perceived behavioural control for alternatives is low.

To illustrate the logic of the TPB, an individual's intention to travel to destination A with mode X is expected to increase when (1) he/she evaluates travelling to destination A with mode X in a positive way, (2) he/she experiences social pressure to travel to destination A with mode X, and/or (3) he/she expects to be able to travel to destination A with mode X.

Studies that use the TPB to explain travel behaviour often find that attitudes and perceived behavioural control play a role in explaining travel behaviour, while the role subjective norms seems rather ambiguous (Bamberg et al., 2003; Bamberg & Schmidt, 2003; Dill et al., 2014; Eriksson & Forward, 2011; Wall et al., 2007; Zailani et al., 2016). Indeed, a meta-analysis by Gardner & Abraham (2008) found that perceived behavioural control and attitudes have a stronger relationship with the intention to drive than subjective norms do.

Table 4 is an overview of the findings of the literature that has been reviewed for the current study. It only concerns literature that used the TPB to explain travel behaviour. For each factor of the TPB it is indicated whether it plays a significant role in explaining the intention to use a certain mode of transport or the actual usage of a certain transport mode.

Table 4
Reviewed literature concerning the association between TPB-based factors and travel behaviour.

Study	N	Sample location	Researched mode of transport	Attitudes	Subjective norms	Perceived behavioural control
Anable (2005)	666	Northwest of the UK	Alternative to car	Yes	-	Yes
Bamberg et al. (2003)	169	Stuttgart (Germany)	Public transport	Yes	Yes	Yes
Bamberg & Schmidt (2003)	321	University of Giessen (Germany)	Car	Yes	Yes	Yes
Dill et al. (2014)	1159	Portland, Oregon (US)	Walking	Yes	No	Yes
			Bicycle	Yes	No	Yes
Eriksson & Forward (2011)	Approx. 620	Municipality of Falun (Sweden)	Car	Yes	Yes	Yes
			Bus	Yes	No	Yes
			Bicycle	Yes	No	Yes
Wall et al. (2007)	1014	De Montfort University (UK)	Car	Yes	Partly	Yes
Zailani et al. (2016)	392	Kuala Lumpur (Malaysia)	Public transport	Yes	No	Yes

In one of the most cited articles using the TPB to explain travel behaviour, Anable (2005) identified six groups of travellers (i.e. segments) with regard to travel preferences, attitudes, and worldviews. Based on this segmentation, it was found that attitudes and perceived behavioural control explained the intention to use an alternative to the car (e.g. public transport). Whether subjective norms also played a role in explaining the intention to use an alternative to the car remained unclear, however (ibid).

Eriksson & Forward (2011) used the TPB to examine whether the intention to use a certain mode of transport on an ordinary trip is explained by different psychosocial factors, depending on mode of transport (i.e. car, bus, or bicycle). It was found that subjective norms only played a role in explaining the intention to use the car. Beside subjective norms, the intention to use the car was also explained by attitudes and perceived behavioural control. In line with Anable (2005), these two factors also played a role in explaining the intention to use the bicycle and the intention to use the bus. Perceived behavioural control was the most important predictor of the intention to use each of the studied modes of transport (Eriksson & Forward, 2011).

In accordance with the findings of Anable (2005) and Eriksson & Forward (2011), Dill et al. (2014) found that attitudes and perceived behavioural control explained the number of walking and cycling trips in the past month, while subjective norms did not. Interestingly, there was a striking difference between walking and cycling behaviour. The frequency of cycling trips was explained best by attitudes, while perceived behavioural control was the best predictor of the number of walking trips (ibid).

Based on a sample amongst university staff and students, Wall et al. (2007) studied the intention to use the car to travel to the university. In line with Eriksson & Forward (2011), it was found that the intention to use the car was explained by attitudes and perceived behavioural control. Whether subjective norms also helped to explain the intention to use the car depended on the conceptualisation of the concept. Also in this study, perceived behavioural control was the most important predictor of the intention to use the car (Wall et al., 2007).

Bamberg & Schmidt (2003) also studied car use for university trips, but only amongst university students. Corresponding with the findings of Eriksson & Forward (2011), subjective norms played an important role in explaining the intention to use the car. Subjective norms had the strongest effect on the intention to use the car (Bamberg & Schmidt, 2003). It must be noted that the sample was biased towards university students. As university students are rather young, they might be rather sensitive to social pressure. Therefore, the effect of subjective norms on the intention to use the car might be smaller for the general population than for students (ibid). In line with Eriksson & Forward (2011) and Wall et al. (2007), attitudes and perceived behavioural control also helped to explain the intention to use the car. Although proposed by the TPB (Ajzen, 1991), a direct relationship between perceived behavioural control and actual car use has not been found (Bamberg & Schmidt, 2003).

In accordance with the findings of Eriksson & Forward (2011), Bamberg et al. (2003) found that attitude and perceived behavioural control played a role in explaining the intention to use public transport. While Eriksson & Forward (2011) found that perceived behavioural control was the most important predictor of the intention to use the bus, the findings of Bamberg et al. (2003) imply that the role of perceived behavioural control in explaining the intention to use public transport is rather modest, compared to the role of subjective norms and attitudes. However, Bamberg et al. (2003) found that perceived behavioural control did have a rather strong direct effect on actual use of public transport. It is striking that Bamberg et al. (2003) also found that subjective norms have the strongest effect on the intention to use public transport, while Eriksson & Forward (2011) only found a small and nonsignificant effect of subjective norms on intention. As suggested by Bamberg & Schmidt (2003), differences in the importance of subjective norms might be due to differences in sample characteristics.

It is striking that the majority of studies concerning travel behaviour focus on one specific trip (e.g. Bamberg & Schmidt, 2003; Wall et al., 2007), do not specify trip purpose (e.g. Anable, 2005; Bamberg et al., 2003; Dill et al., 2014), or both (e.g. Eriksson & Forward, 2011). Therefore, Zailani et al. (2016) used the TPB to examine whether the intention to use public transport is explained by different psychosocial factors, depending on trip purpose (i.e. work/study, shopping, and leisure). It was found that the intention to use public transport was higher for work and study purposes than for shopping purposes and leisure purposes, although significance has not been reported. In line with Eriksson & Forward (2011), it was also found that attitudes and perceived behavioural control explained the intention to use public transport, while subjective norms did not (Zailani et al., 2016). According to Zailani et al. (2016), the importance of TPB-based factors in explaining the intention to use public transport differed per trip purpose.

Thus, the TPB has been found to help explain travel behaviour (Gardner & Abraham, 2008; Hunecke et al., 2010; Pronello & Gaborieau, 2018). More specifically, there is ample evidence that attitudes and perceived behavioural control play a role in explaining travel behaviour. In contrast, evidence for the importance of subjective norms in explaining travel behaviour is rather mixed (Bamberg et al., 2003; Bamberg & Schmidt, 2003; Dill et al., 2014; Eriksson & Forward, 2011; Wall et al., 2007; Zailani et al., 2016).

2.5. Synthesis: towards an integrated conceptual model

While built environment factors, sociodemographic factors, and psychosocial factors all seem to have a simultaneous effect on travel behaviour (e.g. Dill et al., 2014; Ramezani et al., 2018a; 2018b), they were mostly discussed separately from each other in previous sections. The reason is that most of the reviewed literature concerning travel behaviour is fragmented, meaning that different kind of factors are hardly combined to understand travel behaviour. However, there are a number of exceptions in the sense that some studies did combine built environment factors, sociodemographic factors, and psychosocial factors to understand travel behaviour in a holistic approach (e.g. Dill et al., 2014; Ramezani et al., 2018a; 2018b). Following Dill et al. (2014) and Ramezani et al. (2018a; 2018b), it is assumed that built environment factors, sociodemographic factors, and psychosocial factors have a simultaneous effect on travel behaviour. This is illustrated in the conceptual model below (Figure 3).

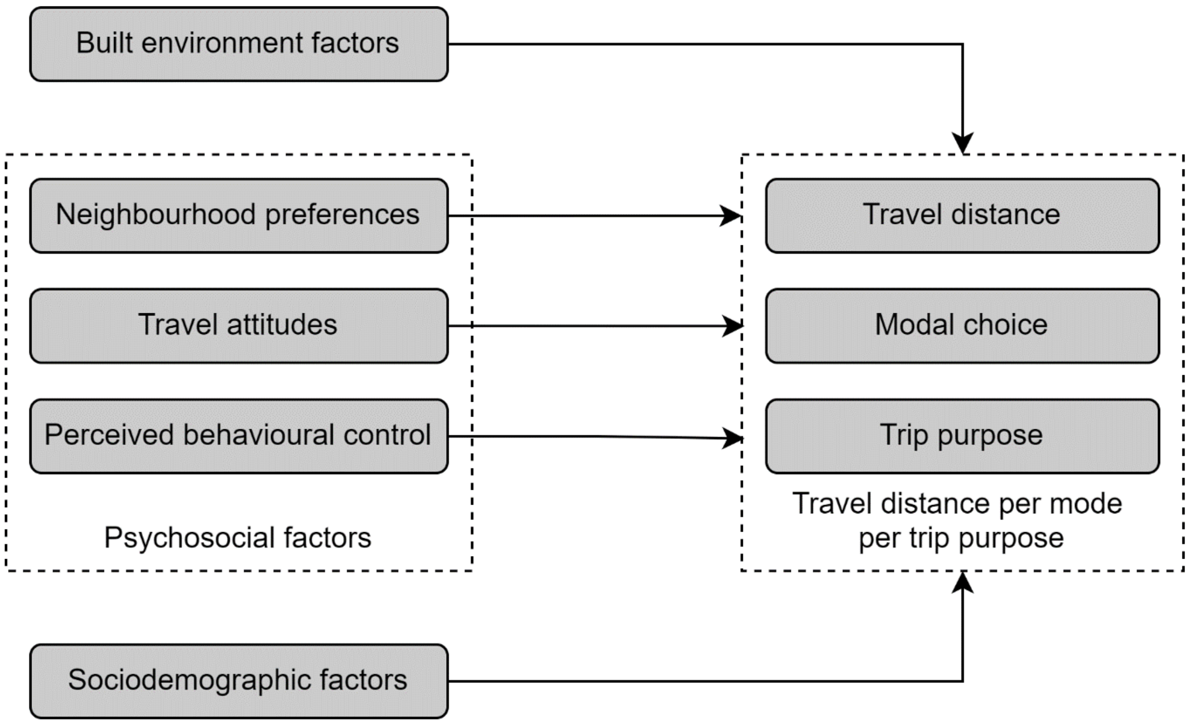

Figure 3
Conceptual model used in this study.

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In order to accurately assess the autonomous effect of the built environment on travel behaviour, at least two psychosocial factors need to be taken into account: travel attitudes and neighbourhood preferences (Ramezani et al., 2018b; Schwanen & Mokhtarian, 2005). Following the TPB, travel attitudes not only help to explain travel behaviour, but perceived behavioural control does so as well (Bamberg et al., 2003; Bamberg & Schmidt, 2003; Dill et al., 2014; Eriksson & Forward, 2011; Wall et al., 2007; Zailani et al., 2016). The number of trips and trip distance are not explicitly included in the conceptual model, as these indicators of travel behaviour have not been addressed in this study as such. Travel distance is used instead, which is the product of the number of trips and trip distance.

Note that the conceptual model only concerns direct effects between built environment factors, sociodemographic factors, and psychosocial factors on the one hand, and travel behaviour on the other hand. However, there might be indirect effects between some of the independent variables as well (De Vos et al., 2021; Dill et al., 2014; Ramezani et al., 2021b). Indirect effects have not been taken into account in this study because of time constraints and analysis restrictions. The possibility for indirect effects is discussed in more detail in Chapter 5.

3. Methodology

3.1. Research approach

The aim of this study was to assess the relationships among variables, i.e. the effect of built environment factors, sociodemographic factors, and psychosocial factors on daily travel behaviour amongst adults in the north of the Netherlands. According to Creswell (2014), a quantitative research approach allows for generalisations and can be used for assessing the relationships among variables. As this ties in with the aforementioned research aim, a quantitative research approach was used.

Given its efficiency and effectiveness in collecting data from a large number of people, a correlational survey design is useful for understanding complex behaviours, like travel behaviour (McLafferty, 2016; Punch, 2014). Therefore, a correlational survey design was used to understand the relationship between built environment factors, sociodemographic factors, and psychosocial factors on the one hand, and travel behaviour on the other hand.

A qualitative research approach has also been considered, but was not deemed adequate for answering the main research question. After all, a qualitative research approach is more appropriate for getting an in-depth understanding of the meanings people ascribe to a specific process or situation (Creswell, 2014). For example, a qualitative research approach would have been useful for understanding how people experience their daily travel to work or study.

In this chapter, methods for data collection (section 3.2.) and data analysis (section 3.3.) are elaborated upon. As choices concerning the methodology of this study are explained, this chapter helps ensure that replication of this study is possible, in order to foster the academic debate about travel behaviour.

3.2. Data collection

3.2.1. Study area: north of the Netherlands

As mentioned in Chapter 1, the north of the Netherlands is used as study area. This region consists of the province of Drenthe, Friesland, and Groningen (Figure 4). The north of the Netherlands is relatively flat and more than 70 percent of land is used for agricultural purposes, compared to roughly 63 percent for the Netherlands as a whole (CLO, 2020). There are some small- to medium-sized cities as well, such as Leeuwarden, Groningen, Assen, and Emmen.

Figure 4
Study area: the north of the Netherlands, consisting of the provinces of Drenthe, Friesland, and Groningen.

The north of the Netherlands has approximately 1,7 million inhabitants (CBS, 2021c). The average population density is 209 inhabitants per square kilometre of land, compared to 421 inhabitants per square kilometre of land in the entire Netherlands (Based on: CBS, 2021c; Waar staat je provincie, 2020). Thus, the study area is relatively sparsely populated, although there are differences between localities within the region.

Table 12 provides more details about the sociodemographic composition of the north of the Netherlands. Besides, travel behaviour of residents in the study area is summarised in Table 5. Compared to the Dutch average, total travel distance is around 12 percent higher amongst residents in the north of the Netherlands. This is not surprising, since amenities are more dispersed in this region (CBS, 2021d). To illustrate, mean distance to a convenience store is 1,3 kilometres in the north of the Netherlands, compared 0,9 kilometres for the Netherlands as a whole (ibid). The total number of trips and total travel time are comparable to the Dutch average, however (CBS, 2021e).

Table 5
Travel behaviour amongst residents in the north of the Netherlands. Values represent mean numbers per resident per month in 2019. Not all values add up due to rounding.
Based on: CBS (2021e; 2021f).

Trip purpose	Trips (number)	Distance (kilometre)	Travel time (hours)
Work/study	24	506	11,3
Free time	28	507	18,2
Shopping	18	132	4,7
Other	12	155	4,1
Total	81	1.299	38,3

Mode of transport	Trips (number)	Distance (kilometre)	Travel time (hours)
Car (as driver)	29	548,2	12,4
Car (as passenger)	10	202,4	4,8
Public transport	5	156,2	4,9
Bicycle	23	91,5	8,2
Walking	13	26,8	5,5

3.2.2. Maptionnaire survey

Primary data was collected by means of a Public Participation Geographic Information System (PPGIS), which is an online map-based survey tool. The added value of such a survey tool is that conventional survey questions can be combined with mapping tasks, in order to collect relevant geographical data which can be analysed in ArcGIS (Ramezani et al., 2021a). As a PPGIS, Maptionnaire has been used in several studies concerning travel behaviour (e.g. Ramezani et al., 2021a; 2021b). At least two of these studies used the collected geographical data to calculate travel distances (Laatikainen et al., 2017; Ramezani et al., 2020). Given the need to calculate monthly travel distances, Maptionnaire was used in this study as well. An overview of the questions and a link to the Maptionnaire survey is provided in Appendix 1.

First, respondents were provided with an explanation of the research project and the structure of the survey. After respondents had confirmed to reside in the province of Drenthe, Friesland, or Groningen, a number of sociodemographic characteristics were collected, such as gender, age, education, and income. In order to assess travel attitudes, respondents were then asked to which extent they agreed or disagreed with fifteen five-point Likert-scale statements relating to daily travel. The statements were copied from Ramezani et al. (2020) to avoid problems with regard to construct validity. The list of statements was a shortened version of the one by Ramezani et al. (2018a), in order to minimise respondent drop out.

The block concerning travel attitudes was followed by a number of mapping tasks. Respondents were first asked to mark their current home location on the map. As respondents might not feel comfortable to reveal their exact home location, it was also possible to locate the marker at the nearest intersection. Subsequently, respondents were asked to think about a typical week in their everyday life and indicate to which common destinations they travel during such a week, considering COVID-19 regulations had become more relaxed. Based on Ramezani et al. (2020), a distinction was made between four destination types: (1) work or study place, (2) place to spend free time, (3) shopping place, and (4) other places to which the respondent travels regularly. Respondents had the opportunity to report more than one place under each category (Figure 5).

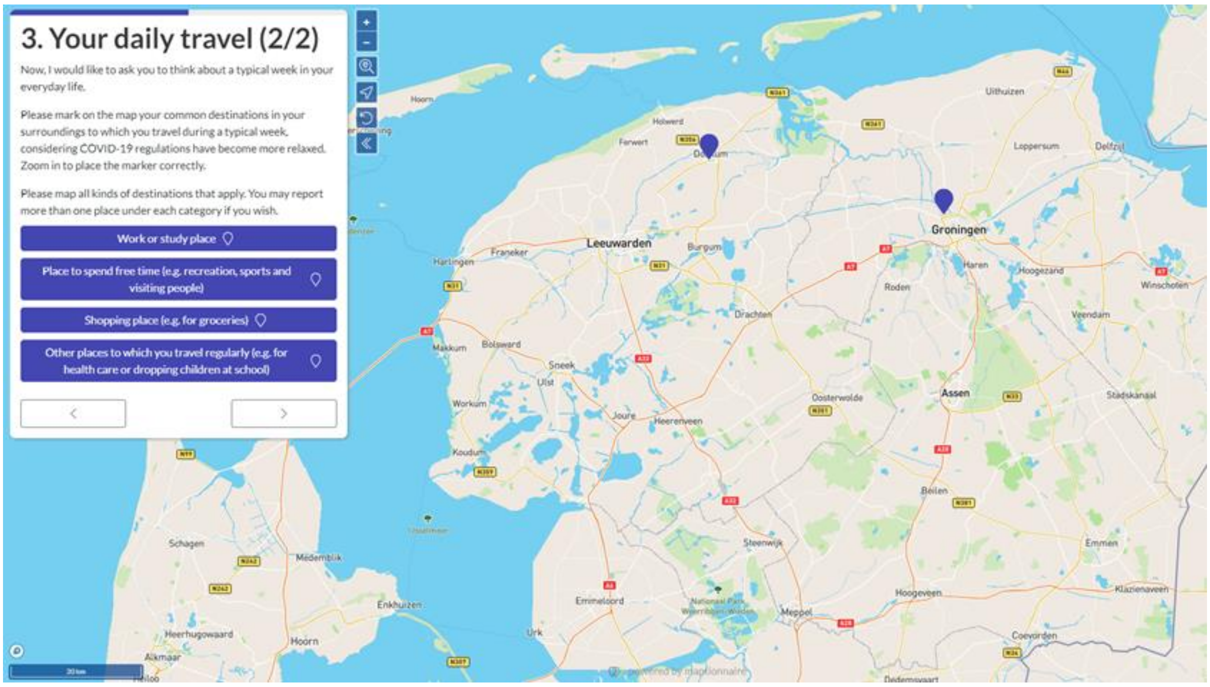

Figure 5
The interface of the Maptionnaire survey. Note that the indicated activity locations (purple dots) are for illustrative purposes and do not reflect the activity locations of any respondent.

After the mapping tasks, twelve five-point Likert-scale statements were presented to assess perceived behavioural control for driving a car, walking, cycling, and taking public transport. In order to ensure construct validity, the statements were based on previous research (e.g. Eriksson & Forward, 2011). Finally, respondents were provided with 29 neighbourhood characteristics. In order to assess neighbourhood preferences, it was asked how important the respondent found each of those neighbourhood characteristics when he/she was choosing his/her current neighbourhood. Importance was measured on a five-point Likert-scale. Similar to the statements concerning travel attitudes, the stated neighbourhood characteristics were adapted from Ramezani et al. (2020) to avoid problems with regard to construct validity. Some of these characteristics had also already been used by Ramezani et al. (2018a) to measure neighbourhood preferences.

Following the block that addressed neighbourhood preferences, respondents were thanked for their participation. Contact details of the researcher were also provided for those who wanted to ask a question or make a comment about the survey. Besides, respondents were given the opportunity to register for a lottery via a separate link to ensure anonymity of the collected data. Those who registered had a chance of winning either of the two VVV vouchers worth €25.

In the light of ethical practice, participation in this study was voluntary and anonymous. Besides, respondents had the opportunity to withdraw from the study without having to provide any explanation. Next to that, answers were only used for the purpose of this study and the collected data was handled confidentially. The data was stored on a password protected device and the data was not shared with third parties. As mentioned in the previous paragraph, contact details of the researcher were provided as well.

Data was collected in the provinces of Drenthe, Friesland and Groningen from September till November 2021, when COVID-19 regulations were not that strict. The Maptionnaire survey was shared with the researcher's friends on Facebook and connections on LinkedIn, in order to reach a large and diverse group of potential respondents. Besides, flyers with information about the research project and a QR code to the survey have been distributed (Appendix 2). Flyer distribution took place in thirty towns and villages in the north of the Netherlands, of which half had a train station (Appendix 3). Town and village selection was not only based on the presence of a train station, but also on inhabitant numbers, in order to ensure sufficient variation in built environment factors. Within each of the selected towns and villages flyers were distributed in a number of different streets to get a diversified sample.

3.2.3. Secondary data

Next to primary data collection by means of a Maptionnaire survey, secondary data was collected as well. As sociodemographic and psychosocial factors had already been covered by the Maptionnaire survey, indicators of different built environment factors were collected from or based on secondary datasets (Table 6). Other variables linked to the built environment (e.g. street design factors, such as availability of street lighting, sidewalks, and planting strips) were not included in this study due to the lack of appropriate data.

A dataset consisting of indicators of built environment factors was provided by the Central Bureau for Statistics (CBS, 2018). The dataset used in this study concerned the year 2018 and indicators were provided per postal code area at PC4 level.[2] More recent datasets

[2] In the Netherlands different levels of postal code areas can be distinguished. A PC4 area (e.g. 9747) typically covers an entire neighbourhood and consists of a number of PC6 areas. A PC6 area (e.g. 9747AD) usually only covers a part of a street. Therefore, datasets at PC4 level are less detailed than datasets at PC6 level.

that included indicators of built environment factors were not (yet) available (CBS, 2021g). Next to this, a shapefile including road intersections in the Netherlands was provided by the Geodienst, a GIS expertise centre of the University of Groningen. It is important to note that the shapefile was based on open source data (i.e. OpenStreetMap) and that it concerned the year 2016, as more recent datasets were not yet available. Based on a LISA-dataset, the number of jobs were provided per postal code area at PC6 level by one of the professors from the University of Groningen.[3] These data concerned the year 2019 and were the most recent ones.

Table 6
Indicators of built environment factors used for statistical analysis.

Built environment factor	Indicator / Variable	Secondary dataset
Density	Population density	Based on: CBS, 2018
Diversity	Distance to nearest convenience store	CBS, 2018
	Distance to nearest department store	CBS, 2018
Design	Intersection density	Based on: OpenStreetMap
Destination accessibility	Number of convenience stores within 1 kilometre	CBS, 2018
	Number of jobs within 5 kilometre	Based on: LISA
Distance to transit	Distance to nearest train station	CBS, 2018

3.3. Data analysis

3.3.1. Data preparation

Before running statistical analyses, the raw survey data required preparation. Data preparation consisted of (1) filtering (potentially) faulty home and activity locations, (2) calculating monthly travel distances per mode of transport, (3) removing and recoding a number of sociodemographic variables, and (4) running factor analyses for travel attitudes, perceived behavioural control, and neighbourhood preferences. ArcGIS 10.5.1. was used for the first two steps, while IBM SPSS Statistics 25 was used for the last two steps.

First, home and activity locations that had not been considered valid, were removed. Home and activity locations were only considered valid if the marker was located on a building or near a building, such as on a crossroads in a neighbourhood. Besides, activity locations were only used for statistical analysis if the respondent had also indicated mode of transport and travel frequency, as these were required for calculating monthly travel distances per mode of transport.

[3] LISA provides data about employment per branch per postal code area.

Second, Euclidean distances between home and activity locations were calculated for each respondent. Note that these distances almost always do not reflect real travel distance due to network design. Real travel distances could have been calculated by means of network analysis, in order to improve validity of the dependent variable(s). However, network analysis has not been used because of time constraints and the lack of a dataset concerning the pedestrian network.

Due to the possibility that an activity took place at home, while a respondent erroneously reported his/her home and/or activity location, trip distances equal or below 25 metres were removed from the analysis. It was assumed that a respondent travelled from home to the activity location and back. Therefore, the calculated Euclidean distances were multiplied by two. Monthly trip distances were calculated by multiplying each of the doubled values by one of the weight factors from Table 7 which were based on frequency of visit reported by the respondent. Finally, monthly travel distances per mode of transport were calculated for 192 respondents by adding up monthly trip distances for each mode of transport. Both total monthly travel distance and monthly travel distance per trip purpose were calculated for each mode of transport.

Table 7
Assigned weights for calculating monthly travel distances. Based on: Soinio (2021).

Relative frequency	Weight
Once a month	1
A couple of time per month	2
Once a week	4
A couple of times a week	8
(Almost) everyday, for work or study	22
(Almost) every day, not for work or study	30

Third, a number of sociodemographic variables were removed or recoded due to small group sizes (i.e. equal or smaller than 10 respondents). Table 8 provides an overview of the remaining sociodemographic variables that have been used for statistical analysis. To illustrate the recoding process, education categories 'undergraduate level', 'graduate level', and 'postgraduate level' have been recoded into 'high education', while 'basic education' and 'secondary education' have been recoded into 'low education'.

Table 8
Sociodemographic factors used for statistical analysis.

Sociodemographic variable	Recoded	Categories after recoding, if applicable
Gender	No	Male
		Female
Age	No	Continuous
Education	Yes	High education (undergraduate, graduate, or postgraduate level)
		Low education (basic or secondary education)
Employment	Yes	Full-time employed (≥ 36 hours a week)
		Part-time employed (< 36 hours a week)
		Student
		Other (unemployed, retired, or other)
Household	Yes	Living alone with/without child/children
		Living with a partner
		Living with a partner and child/children
		Living with my parents/caretakers
		Several people with separate budgets
Number of cars	No	Continuous
Income	Yes	High income (more than €4.500 per month)
		Low income (less than €4.500 per month)
Access to a car	Yes	Always access to a car
		Not always access to a car (multiple times a week, occasionally, or never)
OV-chipkaart	Yes	Yes (full fare, reduced fare, or free)
		No

Fourth, factor analyses were conducted to reduce the number of variables concerning travel attitudes, perceived behavioural control, and neighbourhood preferences. In this way, multicollinearity in statistical analysis could be avoided. The results of factor analysis are summarised in Table 9-11. Based on factor analysis, standardised factor scores had been calculated using the regression method in SPSS. These scores have subsequently been used for statistical analysis.

Table 9 and 10
Factor analysis travel attitudes (TA) and perceived behavioural control (PBC).
Extraction method: Principal component analysis. Rotation method: Varimax with Kaiser normalisation.

Factor	Explained variance (percent)	Measurement indicator	Rotated factor loading
Pro transit	26	TA3: I find it annoying to wait for another travel mode while travelling.	-0,679
		TA6: I like to be able to rest or read while travelling.	0,751
		TA8: I could manage pretty well with one fewer car (or with no car).	0,577
		TA12: I prefer driving to other modes of transportation.	-0,601
		TA13: I prefer to take public transportation than drive whenever possible.	0,763
Pro sustainable travel	12	TA5: I prefer to walk rather than drive whenever possible.	0,703
		TA7: Vehicles should be taxed on the basis of the amount of pollution they produce.	0,614
		TA9: I prefer to cycle rather than drive whenever possible.	0,797
		TA11: I try to limit my driving to help improve air quality.	0,708
Anti-traffic congestion	9	TA14: I like to avoid queues and congestion while travelling.	0,690
		TA15: Changing how people travel is a great way to improve the environment.	0,740
Cost-sensitive	8	TA2: Transit fare affects my choice of daily travel by public transport.	0,785
		TA4: Fuel price and/or price of parking affects my choice of daily travel by car.	0,674
Anti-travel	7	TA1: I find it annoying to have variation in my daily travel time.	-0,577
		TA10: I prefer to organize my errands so that I make as few trips as possible.	0,742

Factor	Explained variance (percent)	Measurement indicator	Rotated factor loading
Perceived behavioural control walking and cycling	42	PBC4: Possibility walking for daily travel from home	0,859
		PBC5: Ease walking for daily travel from home	0,851
		PBC6: Freedom walking for daily travel from home	0,777
		PBC7: Possibility cycling for daily travel from home	0,854
		PBC8: Ease cycling for daily travel from home	0,885
		PBC9: Freedom cycling for daily travel from home	0,737
Perceived behavioural control public transport	18	PBC10: Possibility taking public transport for daily travel from home	0,836
		PBC11: Ease taking public transport for daily travel from home	0,834
		PBC12: Freedom taking public transport for daily travel from home	0,766
Perceived behavioural control driving	13	PBC1: Possibility driving a car for daily travel from home	0,881
		PBC2: Ease driving a car for daily travel from home	0,889
		PBC3: Freedom driving a car for daily travel from home	0,717

Table 11
Factor analysis neighbourhood preferences (NP).
Extraction method: Principal component analysis. Rotation method: Varimax with Kaiser normalisation.

Factor	Explained variance (percent)	Measurement indicator	Rotated factor loading
Walkable neighbourhood where facilities and shops are nearby	21	NP1: Easy to walk and/or cycle in the neighbourhood	0,687
		NP2: Facilities such as a community centre or places to spend free time available nearby	0,463
		NP11: Outdoor recreation opportunities nearby	0,443
		NP15: Easy access to (city) centre	0,648
		NP16: Easy access to a district shopping centre	0,757
		NP17: Safe and convenient to walk and bike for errands	0,796
		NP20: Local shops within walking distance (e.g. grocery store)	0,734
Clean, green and quiet suburban neighbourhood	11	NP5: Spacious housing available	0,480
		NP7: Clean neighbourhood	0,548
		NP8: Parks and green spaces nearby	0,480
		NP22: Quiet neighbourhood	0,831
		NP23: Low level of car traffic on neighbourhood streets	0,726
Socially diverse, vibrant and well-lit neighbourhood	7	NP3: Good street lightning	0,474
		NP25: Diverse neighbours in terms of cultural backgrounds and age	0,713
		NP28: Lots of interaction among neighbours	0,672
		NP29: Many people out and about within the neighbourhood	0,767
Car-oriented neighbourhood	6	NP10: Easy access to highway network or main road	0,809
		NP24: Easy to find parking for residents	0,747
Neighbourhood with easy access to a good public transport service and a proper school or university	6	NP6: Easy access to school or university	0,844
		NP12: Easy access to a good public transport service	0,554
		NP13: Neighbourhood school quality (for my children)	0,681
Neighbourhood near work location, previous home, and social contacts	5	NP4: Tree lined street	-0,471
		NP14: Proximity to work location	0,434
		NP18: Proximity to my previous home	0,638
		NP19: Proximity to my social contacts	0,638
Socially safe and affordable neighbourhood	4	NP9: Safe to walk around at night	0,556
		NP21: Affordability	0,733
Economically homogeneous and attractive neighbourhood	4	NP26: Economic situation of neighbours similar to my level	0,758
		NP27: Attractive appearance of neighbourhood	0,631

3.3.2. Data representativeness

Sociodemographic characteristics of the sample and the adult population of the north of the Netherlands are presented in Table 12. Despite having consciously considered sampling strategy, the sample does not seem to be completely representative of the adult population in the north of the Netherlands. The lack of representativeness is not unique for this study, however. Even when respondents are randomly selected, representativeness can still be an issue, as illustrated by Ramezani et al. (2021b).

Table 12
Sociodemographic characteristics of the sample and the adult population of the north of the Netherlands. Not all values add up due to rounding. Based on: CBS (2019a; 2021c).

	Sample (N = 192)	Population north of the NL
Gender (%)		
Female	58,9	50,3
Male	40,6	49,7
Age, years (%)		
18-35	37,9	25,5
36-50	21,6	21,1
51-64	33,2	26,6
65 or older	7,4	26,9
Highest level of education (%)		
Basic education	5,4	29,8
Upper secondary education	37,0	43,2
Undergraduate level	31,5	18,7
Graduate level or higher	26,1	7,2

With regard to gender, females were overrepresented (58,9% > 50,3%) in the sample. When looking at the age structure of the sample, respondents aged 18-35 years and 51-64 were overrepresented, while respondents aged 65 years or older were clearly underrepresented (7,4% < 26,9%). The latter might be due to relatively low internet use (Niehaves & Plattfaut, 2014) and poor internet skills (Van Deursen & Van Dijk, 2010) amongst the elderly population. While 6 percent of those aged 12 years or older had not used the internet before in 2020 in the Netherlands, this figure was 29 percent for those aged 75 years or older (CBS, 2021h).

Concerning the education profile of the sample, respondents with undergraduate level education and respondents with graduate level education or higher were clearly overrepresented. Those with secondary education were slightly underrepresented (37,0% < 43,2%) in the sample, while respondents with basic education were clearly underrepresented (5,4% < 29,8%). The latter might be due to poor internet skills amongst low educated people (Van Deursen & Van Dijk, 2010).

3.3.3. Statistical analysis

After the raw survey data had been prepared, a number of statistical analyses were conducted. IBM SPSS Statistics 25 was used for this purpose. More specifically, multivariate linear regression analysis was used to assess the effect of built environment factors, sociodemographic factors, and psychosocial factors on monthly travel distances per mode of transport. Regression analysis had also been used in previous studies concerning travel behaviour (e.g. Eriksson & Forward, 2011; Wall et al., 2007).

However, the use of structural equations modelling seems more common in travel behaviour research (e.g. Dill et al., 2014; Ramezani et al., 2021a; 2021b; Zailani et al., 2016). This may be due to its potential to capture complex relationships, in which the dependent variable in one set of relationships is the explanatory variable in another set of relationships (Bagley & Mokhtarian, 2002). Nonetheless, structural equations modelling has not been used in this study because of time constraints and potential limitations regarding sample size. This is also reflected in the conceptual model, which only considers direct effects of built environment factors, sociodemographic factors, and psychosocial factors on monthly travel distances per mode of transport.

Due to the limited number of respondents that indicated to travel by public transport (i.e. 31) or by car as a passenger (i.e. 13), these modes of transport have been excluded from analysis. As the number of respondents that indicated to walk was not that large either (i.e. 43), walking and cycling distance have been combined. Consequently, statistical analyses were conducted for monthly car driving distance and monthly walking and cycling distance (i.e. active transportation). Due to a skewed distribution of the dependent variables and model residuals, monthly car driving distance and monthly active travel distance have been transformed into 10LOG(monthly car driving distance) and 10LOG(monthly active travel distance) respectively.

Table 13 provides an overview of the statistical analyses that have been performed to answer each of the research questions. Note that the analyses for monthly car driving distances were separated from the analyses for monthly active travel distances. First, built environment factors, sociodemographic factors, and psychosocial factors were modelled separately in model 1-6 by using the forward selection method ($p \leq 0,10$). In this way, secondary research question 1-3 could be answered.

Table 13
Statistical analyses linked to each of the secondary research questions.

Model	Dependent variable	Independent variables	Research question
1	Monthly car driving distance	Indicators built environment factors (Table 6)	1, 4
2	Monthly active travel distance	Indicators built environment factors (Table 6)	1, 4
3	Monthly car driving distance	Sociodemographic factors (Table 8)	2, 4
4	Monthly active travel distance	Sociodemographic factors (Table 8)	2, 4
5a	Monthly car driving distance	Psychosocial factors: TA and PBC (Table 9-10)	3, 4
5b	Monthly car driving distance	All psychosocial factors (Table 9-11)	3, 4
6a	Monthly active travel distance	Psychosocial factors: TA and PBC (Table 9-10)	3, 4
6b	Monthly active travel distance	All psychosocial factors (Table 9-11)	3, 4
7	Monthly car driving distance	Significant variables from model 1, 3, 5b, added stepwise per block	1-3
8	Monthly active travel distance	Significant variables from model 2, 4, 6b, added stepwise per block	1-3

Model 1-6 were not only used for total monthly car driving distance and total monthly active travel distance. They were also used for monthly car driving distances and monthly active travel distances for each of the following trip purposes: work or study, shopping, and free time or other. By doing so, secondary research question 4 could be answered as well.

Model 5a and 6a were used to test whether travel attitudes and perceived behavioural control explain travel behaviour, as hypothesised by the TPB (see section 2.4.). Next to travel attitudes and perceived behavioural control, model 5b and 6b included neighbourhood preferences as well.

After each of the factors had been modelled separately, significant variables were combined in model 7 and 8 for explaining total monthly car driving distance and total monthly active travel distance respectively. Significant variables from model 1, 3, and 5b were added stepwise to model 7 to assess the relative importance of each of the factors in explaining total monthly car driving distance. Likewise, significant variables from model 2, 4, and 6b were added stepwise to model 8 to assess the relative importance of each of the factors in explaining total monthly active travel distance. By assessing the relative importance of built environment factors, sociodemographic factors, and psychosocial factors, a more nuanced answer for secondary research question 1-3 could be provided.

4. Results

4.1. Travel behaviour: descriptive statistics

Table 14 provides a summary of travel behaviour in the sample. Travel distances have been calculated as explained in section 3.3. Based on these calculations, it was found that mean monthly car driving distance was 424,3 kilometres, while monthly active travel distance was 56,2 kilometres on average. Respondents travelled most for commuting purposes[4] (518,6 kilometres on average) and least for shopping purposes (23,4 kilometres on average), while travelling for spending free time or other purposes was in between (96,2 kilometres on average). Note, however, that standard deviations were relatively high compared to the mean values. This is due to a number of outliers on both sides of the mean, as illustrated by the minimum and maximum values in Table 14. Outliers have not been removed, as these might be a valid representation of reality.

Table 14
Descriptive statistics of travel behaviour in the sample.

	N	Mean	Standard deviation	Range	
				Minimum	Maximum
Monthly car driving distance (kilometre)	192	424,3	678,3	0	4.015,7
Monthly active travel distance (kilometre)	192	56,2	104,0	0	978,0
Monthly travel distance for commuting purposes (kilometre)	174	518,6	637,2	0	4.015,7
Monthly travel distance for shopping purposes (kilometre)	119	23,4	29,0	0,2	188,4
Monthly travel distance for spending free time or other purposes (kilometre)	118	96,2	178,5	1,3	1.523,7

It is striking that the number of respondents (N) is not the same for every variable in Table 14, which implies that not all respondents reported their work or study place, shopping place, and place to spend free time (or other). This could be a valid representation of reality to a certain extent, as not everyone travels to a work or study place, shopping place, or place to spend free time, for example due to teleworking, unemployment, retirement, distribution of tasks in a household, and the possibility for people to spend free time at home. Despite this, it seems likely that some respondents just did not report all the places they regularly travel to. Although sample size is not particularly small, selective reporting of places respondents travel to might have obscured the results to a small extent.

[4] 'Commuting purposes' is used to refer to 'work or study purposes' to improve readability.

This chapter provides an overview of the results concerning the relationship between built environment factors and travel behaviour (section 4.2.), sociodemographic factors and travel behaviour (section 4.3.), and psychosocial factors and travel behaviour (section 4.4.).

4.2. The role of built environment factors

In the light of secondary research question 1, indicators of built environment factors were used for explaining travel behaviour. The results of multivariate linear regression analysis are summarised in Table 15 and 16 for monthly car driving distance (model 1) and monthly active travel distance (model 2) respectively. In order to be able to answer secondary research question 4, the results are also summarised by trip purpose.

4.2.1. Monthly car driving distance

As summarised in Table 15, it was found that intersection density was negatively related to total monthly car driving distance (-0,193; $p \leq 0,05$). However, intersection density was not found to statistically significantly contribute to model 1 for each of the trip purposes. Instead, monthly car driving distance for commuting purposes was explained by population density (0,185; $p \leq 0,10$) and the number of convenience stores within 1 kilometre (-0,323; $p \leq 0,05$). Monthly car driving distance for shopping purposes was also negatively associated with the number of convenience stores within 1 kilometre (-0,296; $p \leq 0,05$), while monthly car driving distance for spending free time or other purposes was positively related to the number of jobs within 5 kilometre (0,394; $p \leq 0,05$).

The negative association between total monthly car driving distance and intersection density is in line with previous studies. This means that people tend to drive less when street connectivity increases (Ewing & Cervero, 2010; Stevens, 2017). However, only 3 percent of the variance in monthly car driving distance was explained by intersection density in this study.

The finding that monthly car driving distance for commuting purposes is positively related to population density largely contrasts with existing literature. Although trip purpose had not been taken into account, previous studies found that people tend to drive slightly less in areas with a higher population density (Ewing & Cervero, 2010; Stevens, 2017). However, Ramezani et al. (2018a) suggested that there is a densification threshold beyond which sustainable modes of transport become less attractive due to capacity problems. Car driving could therefore become relatively more attractive once that threshold is exceeded, which might explain the positive relationship between monthly car driving distance for commuting purposes and population density. Thus, context likely plays a role in determining the direction of the aforementioned relationship.

Table 15
Relationships between indicators of built environment factors and monthly car driving distance.

	Total		Work or study		Shopping		Free time or other	
	Beta	p value	Beta	p value	Beta	p value	Beta	p value
Population density	-	-	0,185	0,084	-	-	-	-
Intersection density	-0,193	0,028	-	-	-	-	-	-
Number of convenience stores within 1 kilometre	-	-	-0,323	0,003	-0,296	0,025	-	-
Number of jobs within 5 kilometre	-	-	-	-	-	-	0,394	0,009
Model significance		0,028		0,008		0,025		0,009
r^2		0,037		0,107		0,088		0,156
Adjusted r^2		0,030		0,087		0,071		0,135
N		130		89		57		43

The negative relationships between monthly car driving distance for commuting and shopping purposes and the number of convenience stores within 1 kilometre are in line with existing literature. Although the latter variable had not been used as such in previous studies, destination accessibility (i.e. a smaller distance to downtown) was negatively related to total car driving (Ewing & Cervero, 2010; Stevens, 2017). These findings are also endorsed by Ramezani et al. (2021a), as they found a positive association between distance to the city centre and monthly car driving distance.

The finding that car driving distance for spending free time or other purposes is positively related to the number of jobs within 5 kilometre contrasts with previous studies, which found that job accessibility was negatively related to total car driving distance (Ewing & Cervero, 2010; Stevens, 2017). However, the relationship found in this study might not be reliable, as it was based on a relatively small subsample (N=43). According to Hackshaw (2008), a small sample might not yield reliable results.

4.2.2. Monthly active travel distance

As summarised in Table 16, total monthly active travel distance was found to relate to distance to nearest department store (0,165; p≤ 0,10), intersection density (-0,295; p≤ 0,05), the number of convenience stores within 1 kilometre (0,238; p≤ 0,05), and the number of jobs within 1 kilometre (0,307; p≤ 0,05). Monthly active travel distance for commuting purposes was explained by these variables as well, except the number of jobs within 5 kilometre. Monthly active travel distance for shopping purposes was also associated with intersection density (-0,278; p≤ 0,05) and distance to nearest department store, albeit negatively (-0,332; p≤ 0,05). None of these variables statistically significantly contributed to model 2 for spending free time or other purposes. Instead, monthly active travel distance for spending free time or other purposes was negatively related to distance to nearest convenience store (-0,401; p≤ 0,05).

Table 16
Relationships between indicators of built environment factors and monthly active travel distance.

	Total		Work or study		Shopping		Free time or other	
	Beta	p value	Beta	p value	Beta	p value	Beta	p value
Distance to nearest convenience store	-	-	-	-	-	-	-0,401	0.000
Distance to nearest department store	0,165	0,087	0,352	0,012	-0,332	0,007	-	-
Intersection density	-0,295	0,003	-0,389	0,008	-0,278	0,022	-	-
Number of convenience stores within 1 kilometre	0,238	0,033	0,327	0,029	-	-	-	-
Number of jobs within 5 kilometre	0,307	0,002	-	-	-	-	-	-
Model significance		0,000		0,001		0,004		0,000
r^2		0,186		0,253		0,169		0,161
Adjusted r^2		0,157		0,212		0,142		0,149
N		117		58		63		76

The positive associations between monthly active travel distance and distance to nearest department store are not in line with the findings of Ewing & Cervero (2010), as they found a positive relationship between diversity (i.e. smaller distance to a store) and the total number of walking trips. The negative relationship between monthly active travel distance for shopping purposes and distance to nearest department store is in line with these findings, however. A reason might be that carrying heavy shopping purchases discourages people from using active transportation, especially when the distance to the shopping location increases (Kim & Ulfarsson, 2008). Differences in the direction of the relationship between monthly active travel distance and distance to nearest department store illustrates the importance of taking into account trip purpose.

The finding that monthly active travel distance for spending free time or other purposes is negatively related to distance to nearest convenience store is also in accordance with the findings of Ewing & Cervero (2010). These findings are also endorsed by Snellen et al. (2005), as they found that people tend to cycle and walk less when distance to a convenience store increases, although trip purpose had not been taken into account. As convenience stores are regularly located at central locations near other places, a higher distance to a convenience store could indicate living further away from locations where recreational activities take place, which makes the use of active transportation less likely (De Witte et al., 2013; Lin et al., 2018).

The negative associations between monthly active travel distance and intersection density are supported by the findings of Panter et al. (2010), as they found a negative relationship between intersection density and the probability of walking to school. Positive relationships between the number of walking trips and intersection density have also been found, however (Ewing & Cervero, 2010). In the same vein, Dill et al. (2014) concluded that "a well-connected network […] can support higher levels of walking and bicycling" (p. 45). Although intersection density plays a role in explaining monthly active travel distance, the direction of the relationship might ultimately depend on network design, including the number of turns and angular changes between streets (Ramezani et al., 2018a).

The finding that monthly active travel distance is positively related to the number of convenience stores within 1 kilometre is in line with the findings of Dill et al. (2014), as they found that a higher number of destinations within a certain buffer area was associated with more walking and cycling trips. These destinations also included convenience stores.

The positive relationship between total monthly active travel distance and the number of jobs within 5 kilometre is also in line with existing literature. More specifically, Ewing & Cervero (2010) found a positive relationship between the number of jobs within one mile and the number of walking trips.

4.3. The role of sociodemographic factors

In the light of secondary research question 2, sociodemographic factors were used for explaining travel behaviour. The results of multivariate linear regression analysis are summarised in Table 17 and 18 for monthly car driving distance (model 3) and monthly active travel distance (model 4) respectively. In order to be able to answer secondary research question 4, the results are also summarised by trip purpose.

4.3.1. Monthly car driving distance

As summarised in Table 17, it was found that age (-0,225; p≤ 0,05), being a student (-0,198; p≤ 0,05), and having an OV-chipkaart (-0,227; p≤ 0,05) were negatively related to total monthly car driving distance, while being full-time employed (0,186; p≤ 0,05), living with or without children (0,194; p≤ 0,05), and having a high income (0,287; p≤ 0,05) were positively associated with total monthly car driving distance. Besides, it was found that having a high income (0,230; p≤ 0,05) was also positively related to monthly car driving distance for commuting purposes. Next to this, monthly car driving distance for commuting purposes was negatively associated with being part-time employed (-0,352; p≤ 0,05) and living with a partner (-0,186; p≤ 0,10). Model 3 for shopping purposes did not return any statistically significant values, which could be due to small sample size (Andrade, 2020). None of the aforementioned independent variables statistically significantly contributed to model 3 for spending free time or other purposes. Instead, monthly car driving distance for spending free time or other purposes was negatively related to living with parents or caretakers (-0,468; p≤ 0,05).

Table 17
Relationships between sociodemographic factors and monthly car driving distance.

	Total		Work or study		Shopping		Free time or other	
	Beta	p value	Beta	p value	Beta	p value	Beta	p value
Age	-0,225	0,024	-	-	-	-	-	-
Full-time employed	0,186	0,050	-	-	-	-	-	-
Part-time employed	-	-	-0,352	0,002	-	-	-	-
Student	-0,198	0,048	-	-	-	-	-	-
Living alone with/ without child/children	0,194	0,040	-	-	-	-	-	-
Living with a partner	-	-	-0,186	0,097	-	-	-	-
Living with my parents/caretakers	-	-	-	-	-	-	-0.468	0,006
High income	0,287	0,003	0,230	0,043	-	-	-	-
OV-chipkaart	-0,227	0,016	-	-	-	-	-	-
Model significance		0,000		0,001		-		0,006
r^2		0,260		0,209		-		0,219
Adjusted r^2		0,214		0,175		-		0,193
N		114		79		-		41

The negative association between total monthly car driving distance and age is in line with the findings of Snellen et al. (2005), as they found that elderly people were less mobile than younger adults, especially when looking at travel distance by car. In contrast, Ramezani et al. (2020) found that age was positively related to monthly car driving distance, which might be due to differences in context, sample characteristics, and measurement of age.

The finding that total monthly car driving distance is positively associated with being full-time employed is in accordance with previous studies (Ramezani et al., 2020; Snellen et al., 2005). The negative relationship between monthly car driving distance for commuting purposes and being part-time employed is partly supported by the findings of Snellen et al. (2005). Although trip purpose had not been taken into account, part-time employed persons travelled less by car than full-time employed persons, but more than unemployed persons and students (ibid). Snellen et al. (2005) also found that students travelled less by car than full-time employed persons, part-time employed persons, and unemployed persons, which is in line with the finding that total monthly car driving distance is negatively associated with being a student.

While a number of household types (i.e. living alone with or without children, living with a partner, and living with my parents/caretakers) were found to be related to monthly car driving distance, Ramezani et al. (2020) did not find any of these direct relationships. However, Ramezani et al. (2020) did find that persons living alone and persons living alone with children were more likely to belong to a segment of travellers oriented towards the car (compared to persons from other household types), which is in accordance with the findings of this study.

The positive relationships between monthly car driving distance and having a high income are in line with the findings of Ramezani et al. (2020). Although having a high income was not found to be statistically significantly related to monthly car driving distance, Ramezani et al. (2020) found that high income residents were more likely to belong to time-conscious suburbanites (compared to low income residents), which is a segment of travellers oriented towards the car.

The finding that total monthly car driving distance is negatively related to having an OV-chipkaart is also in line with the findings of Ramezani et al. (2020), as they found that owning a cheap transit pass was negatively associated with monthly car driving distance. While an OV-chipkaart might allow people to travel by public transport for free or at a reduced fare, this is not necessarily the case. Therefore, an OV-chipkaart does not necessarily equal a cheap transit pass, however.

4.3.2. Monthly active travel distance

As summarised in Table 18, total monthly active travel distance was found to relate to being a male (0,303; p≤ 0,05), being part-time employed (0,220; p≤ 0,05), living alone with or without children (0,208; p≤ 0,10), and having always access to a car (-0,287; p≤ 0,05). However, none of these independent variables were found to statistically significantly contribute to model 4 for each of the trip purposes. Instead, monthly active travel distance for commuting purposes was explained by education level: being highly educated (0,330; p≤ 0,10) was positively associated with monthly active travel distance for commuting purposes. Monthly active travel distance for shopping purposes was positively related to living with a partner (0,280; p≤ 0,10), while monthly active travel distance for spending free time or other purposes was associated with having an OV-chipkaart (0,029; p≤ 0,05) and living with a partner and children (-0,237; p≤ 0,10).

Table 18
Relationships between sociodemographic factors and monthly active travel distance.

	Total		Work or study		Shopping		Free time or other	
	Beta	p value	Beta	p value	Beta	p value	Beta	p value
Gender / Male	0,303	0,006	-	-	-	-	-	-
Highly educated	-	-	0,330	0,061	-	-	-	-
Part-time employed	0,220	0,045	-	-	-	-	-	-
Living alone with/without child/children	0,208	0,051	-	-	-	-	-	-
Living with a partner	-	-	-	-	0,280	0,098	-	-
Living with a partner and child/children	-	-	-	-	-	-	-0,237	0,089
Always access to a car	-0,287	0,009	-	-	-	-	-	-
OV-chipkaart	-	-	-	-	-	-	0,308	0,029
Model significance		0,001		0,061		0,098		0,010
r^2		0,121		0,109		0,078		0,180
Adjusted r^2		0,104		0,080		0,051		0,144
N		108		57		61		76

The positive association between total monthly active travel distance and being a male is in line with previous studies. According to Dill et al. (2014), the number of walking and cycling trips was negatively related to being a female, while Ramezani et al. (2018b) found that the probability of walking was lower for females than for males.

The finding that monthly active travel distance for commuting purposes is positively associated with being highly educated is also in accordance with existing literature. Ramezani et al. (2018a; 2018b) found that education level was positively related to the probability of sustainable mode choice (i.e. walking, bicycle, and public transport) for work trips. Although trip purpose had not been taken into account, Dill et al. (2014) found that the number of walking and cycling trips was positively associated with education level, albeit indirectly via a number of psychological constructs. In the same vein, Snellen et al. (2005) found that highly educated persons tend to cycle and walk more than persons with lower education levels.

The positive relationship between total monthly active travel distance and being part-time employed is not supported by the findings of Snellen et al. (2005). Part-time employed persons were founds to travel less by active transportation modes than full-time employed persons and students (ibid). Differences in context and sample characteristics might explain this difference.

It is striking that the associations between monthly active travel distance and a number of household types (i.e. living with a partner and living with a partner and children) contrasted with the findings of Ramezani et al. (2020). Nonetheless, Ramezani et al. (2020) did find that persons living alone with or without children were more likely to belong to a segment of travellers oriented towards the car (compared to persons from other household types), which is in accordance with the findings of this study. It must be also noted that the relationships between monthly active travel distance and each of the household types were only found to be significant at the 10%-level in this study. This means there is still a considerable chance household type does not explain monthly active travel distance at all.

The finding that total monthly active travel distance is negatively related to having always access to a car is in line with the findings of Ramezani (2020), as they found that the number of cars in the household (and therefore logically having greater access to a car) was negatively associated with both walking distance and cycling distance. The positive relationship between monthly active travel distance for spending free time or other purposes and having an OV-chipkaart was also in line with existing literature. Ramezani et al. (2018b) found that owning a transit pass was positively related to sustainable mode choice for both work and non-work trips.

4.4. The role of psychosocial factors

In the light of secondary research question 3, psychosocial factors were used for explaining travel behaviour. The results of multivariate linear regression analysis for monthly car driving distance are summarised in Table 19 and 20 (model 5a and 5b respectively), while those for monthly active travel distance are summarised in Table 21 and 22 (model 6a and 6b respectively). Table 19 and 21 only include travel attitudes and perceived behavioural control to explain travel behaviour. Next to travel attitudes and perceived behavioural control, Table 20 and 22 include neighbourhood preferences as well. In order to be able to answer secondary research question 4, the results are also summarised by trip purpose.

4.4.1. Monthly car driving distance

Regarding model 5a (Table 19), it was found that pro transit attitudes (-0,272; p≤ 0,05), anti-travel attitudes (-0,216; p≤ 0,05), and perceived behavioural control for walking and cycling (-0,307; p≤ 0,05) were negatively related to total monthly car driving distance. Perceived behavioural control for walking and cycling (-0,299; p≤ 0,05) was also found to statistically contribute to model 5a for commuting purposes. Monthly car driving distance for shopping purposes was explained by perceived behavioural control for public transport (-0,294; p≤ 0,05) and perceived behavioural control for driving (-0,231; p≤ 0,10). Model 5a for spending free time or other purposes did not return any significant values, which could be due to small sample size (Andrade, 2020).

Table 19
Relationships between travel attitudes and perceived behavioural control, and monthly car driving distance.

	Total		Work or study		Shopping		Free time or other	
	Beta	p value	Beta	p value	Beta	p value	Beta	p value
TA pro transit	-0,272	0,001	-	-	-	-	-	-
TA anti-travel	-0,216	0,011	-	-	-	-	-	-
PBC walking and cycling	-0,307	0,000	-0,299	0,009	-	-	-	-
PBC public transport	-	-	-	-	-0,294	0,036	-	-
PBC driving	-	-	-	-	-0,231	0,097	-	-
Model significance		0,000		0,009		0.009		-
r^2		0,234		0,090		0,178		-
Adjusted r^2		0,213		0,077		0,143		-
N		115		79		54		-

The relationships between monthly car driving distance on the one hand and pro transit attitudes and anti-travel attitudes on the other hand have not been explored as such by previous studies. Although Ramezani et al. (2018a; 2018b) used comparable travel attitudes, the effect of each of those was only assessed for sustainable mode choice in comparison to the car. Relative to the car, pro transit attitudes were positively related to sustainable mode choice for both work and non-work trips (ibid). This implies that pro transit attitudes are negatively associated with car use relative to sustainable modes of transport, which supports the findings of this study.

In comparison to the car, anti-travel attitudes were positively related to sustainable mode choice, albeit for work trips only (Ramezani et al., 2018b). This means that anti-travel attitudes are negatively associated with car use relative to sustainable modes of transport, which is in line with the findings of this study. However, Ramezani et al. (2018a) found the opposite for both work and non-work trips, which seems to contradict the findings of this study. Nonetheless, Ramezani et al. (2018a) did not assess the effect of travel attitudes on absolute car driving distance. While the car might become relatively more attractive for persons with stronger anti-travel attitudes, this does not necessarily mean that absolute car driving distance is higher for persons with stronger anti-travel attitudes.

The negative associations between monthly car driving distance and perceived behavioural control for active travel and using public transport is in accordance with the findings of Wall et al. (2007). Although their study only concerned commuting trips, Wall et al. (2007) found that perceived behavioural control for alternatives to the car was positively related to the intention to reduce car use. In line with the findings in this study, Wall et al. (2007) also found that perceived behavioural control had a stronger effect than attitudes.

The finding that monthly car driving distance for shopping purposes is negatively associated with perceived behavioural control for driving contrasts with existing literature. Previous studies found that perceived behaviour control for driving was positively related to the intention to use the car, although shopping trips had not been studied in particular (Bamberg & Schmidt, 2003; Eriksson & Forward, 2011). The relationship found in this study might deviate from existing literature because perceived behavioural control was only measured in general terms (i.e. for daily travel from home), while perceived behavioural control has been found to be different for different trip purposes (Zailani et al., 2016). Besides, the negative relationship in this study was only significant at the 10%-level.

After adding neighbourhood preferences, the model fit (r^2) increased for each of the monthly car driving distances. At the same time, a similar pattern emerged for travel attitudes and perceived behavioural control (Table 20). Total monthly car driving distance was still negatively related to pro transit attitudes (-0,272; $p \leq 0,05$), anti-travel attitudes (-0,216; $p \leq 0,05$), and perceived behavioural control for walking and cycling (-0,324; p≤

0,05). Next to these factors, total monthly car driving distance was also explained by a neighbourhood preference for easy access to a good public transport service and a proper school or university (-0,182; p≤ 0,10) and a preference for a clean, green, and quiet suburban neighbourhood (0,171; p≤ 0,10).

Table 20
Relationships between psychosocial factors and monthly car driving distance.

	Total		Work or study		Shopping		Free time or other	
	Beta	p value	Beta	p value	Beta	p value	Beta	p value
TA pro transit	-0,214	0,025	-	-	-	-	-	-
TA cost-sensitive	-	-	-	-	-	-	0,294	0,055
TA anti-travel	-0,231	0,011	-	-	-	-	-	-
PBC walking and cycling	-0,324	0,000	-0,301	0,014	-	-	-	-
PBC public transport	-	-	-	-	-0,274	0,062	-	-
NP easy access to a good public transport service and a proper school or university	-0,182	0,056	-0,236	0,052	-	-	-	-
NP walkable neighbourhood where facilities and shops are nearby	-	-	-	-	-0,367	0,014	-	-
NP clean, green, and quiet suburban neighbourhood	0,171	0,057	-	-	-	-	-	-
NP socially safe and affordable neighbourhood	-	-	-	-	-	-	0,425	0,007
Model significance		0,000		0,009		0,002		0,004
r^2		0,320		0,147		0,266		0,284
Adjusted r^2		0,281		0,118		0,228		0,241
N		94		66		45		36

Also in model 5b (Table 20) perceived behavioural control for walking and cycling (-0,301; p≤ 0,05) was negatively associated with monthly car driving distance for commuting purposes. A neighbourhood preference for easy access to a good public transport service and a proper school or university (-0,236; p≤ 0,10) was also negatively related to monthly car driving distance for commuting purposes. It was found that perceived behavioural control for public transport (-0,274; p≤ 0,10) was still negatively related to monthly car driving distance for shopping purposes. Next to perceived behavioural control for public transport, it was also found that a preference for a walkable neighbourhood where facilities and shops are nearby (-0,367; p≤ 0,05) was negatively associated with monthly car driving distance for shopping purposes. Contrary to model 5a (Table 19), model 5b for spending free time or other purposes returned two statistically significant values. Monthly car driving distance for spending free time or other purposes was explained by cost-sensitive travel attitudes (0,294; p≤ 0,10) and a preference for a socially safe and affordable neighbourhood (0,425; p≤ 0,05).

The positive relationship between cost-sensitive travel attitudes and monthly car driving distance for spending free time or other purposes is not in line with the findings of Ramezani et al. (2018a; 2018b). In comparison to the car, cost-sensitive attitudes were positively related to sustainable mode choice for non-work trips, which implies a negative association between cost-sensitive attitudes and car use (ibid). However, the positive relationship found in this study might be due to the fact that car driving has become relatively cheaper than using public transport (CBS, 2019b). Also in absolute terms, car driving is mostly cheaper than using public transport when travelling with multiple persons (Nibud, 2021). At the same time, walking and cycling might not be feasible alternatives for the car due to relatively long travel distances for leisure activities.

The negative associations between monthly car driving distance on the one hand, and (1) a neighbourhood preference for easy access to a good public transport service and a proper school or university and (2) a preference for a walkable neighbourhood where facilities and shops are nearby on the other hand, are largely supported by previous studies. According to Handy et al. (2005), weekly car driving distance by persons living in a suburban neighbourhood was negatively related to a preference for an accessible neighbourhood and a preference for a neighbourhood that supports physical activity. However, the effect was small and the opposite was true for persons living in a traditional neighbourhood (ibid). Next to this, Ramezani et al. (2018b) implied that a preference for a walkable neighbourhood, including easy access to a public transport service, is indeed negatively associated with car use relative to sustainable modes of transport. However, Ramezani et al. (2018b) did not take into account access to a proper school or university and access to facilities and shops in their operationalisation of walkable neighbourhoods.

The finding that total monthly car driving distance is positively related to a preference for a clean, green, and quiet suburban neighbourhood is in accordance with existing literature. According to Dieleman et al. (2002), car driving distances are longer in suburban settings than in urban settings due to higher distances between activities in the former. Besides, Ramezani et al. (2018a) implied that a preference for a safe and secure neighbourhood, including a low level of car traffic and quietness, is positively related to car use relative to walking. Note that this only went for work trips, and cleanness and greenness of the neighbourhood were not taken into account by Ramezani et al. (2018a), however.

The positive relationship between monthly car driving distance for spending free time or other purposes and a preference for a socially safe and affordable neighbourhood is partly in line with previous studies. De Bruyne & Van Hove (2013) implies that more affordable neighbourhoods are typically located further away from jobs and services, which increases car driving distances (Dieleman et al., 2002). In contrast, Ramezani et al. (2018b) implied that a preference for a safe and secure neighbourhood is negatively related to car use relative to walking. However, Ramezani et al. (2018b) did not assess the absolute effect of neighbourhood preferences on car use and affordability of housing had not been taken into account.

4.4.2. Monthly active travel distance

Regarding model 6a (Table 21), monthly active travel distance was found to relate to perceived behavioural control for walking and cycling (0,248; $p \leq 0,05$) and perceived behavioural control for driving (-0,240; $p \leq 0,05$). Model 6a for commuting purposes did not return any statistically significant values, which could be due to small sample size (Andrade, 2020). Monthly active travel distance for shopping purposes was explained by anti-traffic congestion attitudes (-0,319; $p \leq 0,05$) and cost-sensitive travel attitudes (0,227; $p \leq 0,10$). It was found that monthly active travel distance was positively associated with pro transit attitudes (0,217; $p \leq 0,10$).

The positive association between total monthly active travel distance and perceived behavioural control for walking and cycling is supported by existing literature. Previous studies found that perceived behavioural control for active travel was positively related to the intention to use the bicycle (Eriksson & Forward, 2011) and the number of walking and cycling trips (Dill et al., 2014). The relationship between total monthly active travel distance and perceived behavioural control for driving has not been assessed by previous studies, however. Studies using perceived behavioural control are typically only concerned with the association between perceived behavioural control for the mode of transport that is being studied (e.g. Bamberg & Schmidt, 2003; Dill et al., 2014; Eriksson & Forward, 2011). Nonetheless, a negative relationship between total monthly active travel distance and perceived behavioural control for driving seems plausible. After all, the intention to use the car is positively associated with perceived behavioural control for driving (Bamberg & Schmidt, 2003; Eriksson & Forward, 2011). If people, as a consequence of a higher perceived behavioural control for driving, drive more often at the expense of walking and cycling then indeed a negative association between monthly active travel distance and perceived behavioural control for driving can be found.

Table 21
Relationships between travel attitudes and perceived behavioural control, and monthly active travel distance.

	Total		Work or study		Shopping		Free time or other	
	Beta	p value	Beta	p value	Beta	p value	Beta	p value
TA pro transit	-	-	-	-	-	-	0,217	0,071
TA anti-traffic congestion	-	-	-	-	-0,319	0,016	-	-
TA cost-sensitive	-	-	-	-	0,227	0,082	-	-
PBC walking and cycling	0,248	0,009	-	-	-	-	-	-
PBC driving	-0,240	0,011	-	-	-	-	-	-
Model significance		0,001		-		0,019		0,071
r^2		0,121		-		0,140		0,047
Adjusted r^2		0,104		-		0,107		0,033
N		113		-		58		70

The finding that monthly active travel distance for spending free time or other purposes is positively related to pro transit attitudes is in line with the findings of Ramezani et al. (2018a). In comparison to the car, pro transit attitudes were positively associated with walking for both work and non-work trips. While Ramezani et al. (2018b) also found such a positive relationship between sustainable mode choice and pro transit attitudes, this only concerned work trips rather than non-work trips.

The negative association between monthly active travel distance for shopping purposes and anti-traffic congestion attitudes seems striking, although the relationship has not been assessed by previous studies yet. However, it could be that persons with stronger anti-traffic congestion attitudes are more likely to live near shopping locations, resulting in lower active travel distances. Future research should assess the validity of this hypothesis.

The positive relationship between monthly active travel distance for shopping purposes and cost-sensitive travel attitudes is supported by the findings of Ramezani et al. (2018a). Relative to the car, cost-sensitive travel attitudes were positively associated with walking for non-work trips. Ramezani et al. (2018b) only found such a positive relationship between sustainable mode choice and cost-sensitive travel attitudes for work-trips, however.

After adding neighbourhood preferences, the model fit (r^2) increased for each of the monthly active travel distances. At the same time, a slightly different pattern emerged for travel attitudes and perceived behavioural control (Table 22). Total monthly active travel distance was still explained by perceived behavioural control for walking and cycling (0,228; p≤ 0,05) and perceived behavioural control for driving (-0,188; p≤ 0,10). Next to these factors, total monthly active travel distance was also negatively related to a preference for a car-oriented neighbourhood (-0,311; p≤ 0,05), a preference for a neighbourhood near work location, previous home, and social contacts (-0,197; p≤ 0,05), and a neighbourhood preference for easy access to a good public transport service and a proper school or university (-0,234; p≤ 0,05).

Table 22
Relationships between psychosocial factors and monthly active travel distance.

	Total		Work or study		Shopping		Free time or other	
	Beta	p value	Beta	p value	Beta	p value	Beta	p value
TA anti-traffic congestion	-	-	-	-	-0,382	0,007	-	-
TA cost-sensitive	-	-	-	-	-	-	-0,225	0,071
TA anti-travel	-	-	-	-	-0,346	0,013	-	-
PBC walking and cycling	0,228	0,019	-	-	-	-	-	-
PBC driving	-0,188	0,079	-	-	-	-	-	-
NP walkable neighbourhood where facilities and shops are nearby	-	-	-	-	0,271	0,051	-	-
NP car-oriented neighbourhood	-0,311	0,004	-	-	-	-	-0,446	0,001
NP easy access to a good public transport service and a proper school or university	-0,234	0,017	-0,270	0,084	-	-	-	-
NP near work location, previous home, and social contacts	-0,197	0,043	-	-	-	-	-	-
Model significance		0,000		0,084		0,005		0,001
r^2		0,322		0,073		0,263		0,255
Adjusted r^2		0,277		0,050		0,211		0,226
N		89		44		46		53

The latter factor was also found to be negatively associated with monthly active travel distance for commuting purposes (-0,270; p≤ 0,10). Also in model 6b (Table 22) anti-traffic congestion attitudes (-0,382; p≤ 0,05) were negatively related to monthly active travel distance for shopping purposes, but anti-travel attitudes (-0,346; p≤ 0,05) and a preferences for a walkable neighbourhood where facilities and shops are nearby (0,271; p≤ 0,10) also played a role in explaining monthly active travel distance for shopping purposes. It was found that monthly active travel distance for spending free time or other purposes was negatively associated with cost-sensitive travel attitudes (-0,225; p≤ 0,10) and a preference for a car-oriented neighbourhood (-0,446; p≤ 0,05).

The negative relationship between monthly active travel distance for shopping purposes and cost-sensitive travel attitudes contrasts with the findings from Table 21 and the findings of Ramezani et al. (2018a), as discussed before. It must be noted that the negative relationship in this study was only significant at the 10%-level, meaning there is still a notable chance cost-sensitive travel attitudes do not explain monthly active travel distance for spending free time or other purposes at all. The finding that monthly active travel distance for shopping purposes is positively related to anti-travel attitudes is supported by the findings of Ramezani et al. (2018b). In comparison to the car, anti-travel attitudes were negatively related to sustainable mode choice for both work and non-work trips.

Associations between monthly active travel distance and a preference for a car-oriented neighbourhood have not been analysed in previous studies. Nonetheless, the finding that monthly active travel distance is negatively related to a preference for a car-oriented neighbourhood seems plausible. In this study it was found that a preference for a car-oriented neighbourhood negatively correlated with pro sustainable travel attitudes (r = -349). While the latter variable was not found to be associated with monthly active travel distance in this study, previous studies found that travel attitudes in favour of active travel were positively related to the intention to use the bicycle (Eriksson & Forward, 2011) and the number of walking and cycling trips (Dill et al., 2014).

The negative relationships between monthly active travel distance and a neighbourhood preference for easy access to a good public transport service and a proper school or university have not been touched upon by previous academics. An explanation of this finding could be that neighbourhood preferences for ease access to a good public transport service and a proper school or university were positively correlated with pro transit attitudes. Although this correlation was only weak (r = 0,211), previous studies found that attitudes towards public transport were positively associated with the intention to use public transport (Bamberg et al., 2003; Zailani et al., 2016). If people indeed have easy access to a good public transport service, it might be that they travel more often by public transport at the expense of active transportation modes. Future research should test whether this hypothesis is valid.

The positive association between monthly active travel distance for shopping purposes and a preference for a walkable neighbourhood where facilities and shops are nearby is in line with existing literature. According to Handy et al. (2006), proximity to activities is positively related to the number of walking trips. Next to this, Ramezani et al. (2018b) found that a preference for a walkable neighbourhood was positively associated with walking for both work and non-work trips.

Unfortunately, it is unclear why a preference for a neighbourhood near work location, previous home, and social contacts is negatively related to total monthly active travel distance. It is possible that this neighbourhood preference does not match with the actual neighbourhood, which is referred to as 'residential dissonance' (De Vos et al., 2012). This dissonance might have produced a counterintuitive regression value.

4.5. Towards a holistic understanding of travel behaviour

In the previous sections the effects of built environment factors, sociodemographic factors, and psychosocial factors on monthly travel distances have been discussed independent from each other. In reality built environment factors, sociodemographic factors, and psychosocial factors might all affect travel behaviour simultaneously, however (Cao et al., 2009; Cervero & Kockelman, 1997; Guan et al., 2020; Ramezani et al., 2018a; 2018b; 2020). Therefore, significant variables from previous models have been combined to assess the relative importance of built environment factors, sociodemographic factors, and psychosocial factors to explain monthly travel distances.

The results of multivariate linear regression analysis are summarised in Table 23 and 24 (model 7 and 8 respectively). This makes it possible to put the previously discussed results in perspective and provide a more nuanced answer to each of the secondary research questions. It is striking that p values are rather high for a number of variables, especially when comparing them with the p values in the models discussed in previous sections. As there were no issues regarding multicollinearity, a reason for the high number of nonsignificant variables could be that sample size is relatively small (Cohen, 1992). Note that Table 23 and 24 only concern total monthly car driving distance and total monthly active travel distance. The outcomes of model 7 and 8 for each of the trip purposes have not been reported due to potential reliability issues related to small subsample sizes.

Regarding total monthly car driving distance, sociodemographic factors were found to explain 25,6 percent of the total variance in the data (Table 23). After adding psychosocial factors this percentage increased to 41,7 percent, which means that psychosocial factors increased model fit by 16,1 percentage points. Subsequently, a built environment factor was added to the model, which increased model fit by another 1,8 percentage points to get an r square of 0,435 (adjusted r^2: 0,341). Given the small contribution of built environment factors after controlling for sociodemographic factors and psychosocial factors, the role of built environment factors for explaining total monthly car driving distance seems almost negligible.

Table 23
Relationships between sociodemographic (SD), psychosocial (PS), and built environment (BE) factors on the one hand and total monthly car driving distance on the other hand.

	SD		SD + PS		SD + PS + BE	
	Beta	p value	Beta	p value	Beta	p value
Age	-0,276	0,019	-0,252	0,032	-0,244	0,036
Full-time employed	0,255	0,019	0,108	0,301	0,131	0,214
Student	-0,159	0,171	-0,198	0,090	-0,191	0,099
Living alone with/without children	0,218	0,044	0,180	0,079	0,208	0,044
High income	0,287	0,013	0,213	0,047	0,217	0,042
OV-chipkaart	-0,255	0,016	-0,175	0,087	-0,167	0,099
TA pro transit	-	-	-0,149	0,154	-0,142	0,171
TA anti-travel	-	-	-0,100	0,327	-0,088	0,384
PBC walking and cycling	-	-	-0,300	0,003	-0,293	0,003
NP easy access to a good public transport service and a proper school or university	-	-	-0,132	0,194	-0,141	0,161
NP clean, green and quiet suburban neighbourhood	-	-	0,171	0,072	0,124	0,209
Intersection density	-	-	-	-	-0,146	0,134
Model significance		0,001		0,000		0,000
r^2		0,256		0,417		0,435
Adjusted r^2		0,199		0,329		0,341
N		85		85		85

Concerning total monthly active travel distance, 35,4 percent of the total variance in the data was explained by sociodemographic factors (Table 24). Model fit increased by 12,5 percentage points to 47,9 percent after adding psychosocial factors. After adding built environment factors this percentage increased by 2,3 percentage points to get an r square of 0,502. Thus, also for explaining total monthly active travel distance the role of built environment factors seems only minor. Adjusted r square even decreased from 0,416 to 0,409 after built environment factors had been added to the sociodemographic factors and psychosocial factors to explain total monthly active travel distance.

Table 24
Relationships between sociodemographic (SD), psychosocial (PS), and built environment (BE) factors on the one hand and total monthly active travel distance on the other hand.

	SD		SD + PS		SD + PS + BE	
	Beta	p value	Beta	p value	Beta	p value
Gender / Male	0,373	0,000	0,300	0,002	0,264	0,011
Part-time employed	0,314	0,003	0,345	0,001	0,310	0,006
Living alone with/without children	0,178	0,058	0,121	0,170	0,105	0,276
Always access to a car	-0,501	0,000	-0,340	0,005	-0,291	0,025
PBC walking and cycling	-	-	0,164	0,059	0,144	0,130
PBC driving	-	-	-0,094	0,365	-0,086	0,441
NP car-oriented neighbourhood	-	-	-0,199	0,057	-0,182	0,111
NP easy access to a good public transport service and a proper school or university	-	-	-0,245	0,011	-0,243	0,017
NP near work location, previous home, and social contacts	-	-	-0,154	0,075	-0,147	0,096
Distance to nearest department store	-	-	-	-	0,099	0,352
Intersection density	-	-	-	-	-0,127	0,217
Number of convenience stores within 1 kilometre	-	-	-	-	0,110	0,403
Number of jobs within 5 kilometre	-	-	-	-	0,058	0,658
Model significance		0,000		0,000		0,000
r^2		0,354		0,479		0,502
Adjusted r^2		0,321		0,416		0,409
N		84		84		84

The finding that built environment factors hardly play a role in explaining monthly travel distances is striking. Nonetheless, the Netherlands has a long history in planning practice focussing on compact development (Dieleman & Wegener, 2004; Schwanen et al., 2004). Consequently, there might be relatively little variation in built environment factors in the Netherlands, which could explain the marginal role of built environment factors in explaining travel behaviour. The small number of indicators of built environment factors might also explain this (see section 5.3.).

Nonetheless, the findings in this study are in line with existing literature. According to Cao et al. (2009), the autonomous influence of built environment factors on travel behaviour seems indeed “relatively small compared to the contributions of socio-demographic and unmeasured variables” (p. 390). After all, the role of built environment factors in explaining travel behaviour decreases substantially once factors relating to residential self-selection, such as travel attitudes and neighbourhood preferences, are taken into account (ibid). In line with this, Cervero & Kockelman (1997) found that the effects of built environment factors on travel behaviour “were modest to moderate at best” (p. 216). Despite the seemingly marginal direct effects of built environment factors on travel behaviour, the built environment also seems to affect travel behaviour indirectly, however (see section 5.3.) (De Vos et al., 2021; Dill et al., 2014; Ramezani et al., 2021b).

5. Discussion and conclusion

5.1. Summary of research findings

This study aimed at assessing the effect of built environment factors, sociodemographic factors, and psychosocial factors to explain daily travel behaviour amongst adults in the north of the Netherlands. In order to achieve this research objective, an online map-based survey tool was distributed to collect relevant (geographical) data. Complemented by secondary datasets concerning indicators of built environment factors, factor analysis and multivariate linear regression analysis were used to analyse the collected data.

The empirical data largely support the conceptual model as proposed in Figure 3. After all, built environment factors, sociodemographic factors, and psychosocial factors were found to be related to both monthly car driving distance and monthly active travel distance, albeit to different extents. As a psychosocial factor, travel attitudes did not seem to explain total monthly active travel distance, however. Nonetheless, travel attitudes were found to be associated with monthly active travel distance for some trip purposes, which illustrates the importance of considering trip purposes when studying travel behaviour.

Regarding built environment factors, both total monthly car driving distance and total monthly active travel distance were negatively related to intersection density, which is an indicator of design. Besides, total monthly active travel distance was positively associated with indicators of destination accessibility and diversity. In line with previous studies, the role of built environment factors in explaining travel behaviour was found to be rather small, especially after sociodemographic and psychosocial factors had been controlled for (Cao et al., 2009). This might be due to relatively little variation in built environment factors in the study area and the small number of indicators of built environment factors that had been used in the analysis. Furthermore, it seems that monthly travel distances were explained by different (indicators of) built environment factors for different trip purposes, which is endorsed by Meurs & Haaijer (2001).

Unlike built environment factors, the role of sociodemographic factors in explaining travel behaviour seems substantial. Both total monthly car driving distance and total monthly active travel distance were explained by employment status and household type. Being full-time employed was positively associated with car driving, while being part-time employed was positively related to active travel. Besides, students (compared to non-students) tended to travel less by car, but not necessarily more by active transportation modes. Household type 'living alone with or without children' was positively associated with both total monthly car driving distance and total monthly active travel distance. Next to this, total monthly car driving distance was negatively related to age and having an OV-chipkaart, while having a high income was positively associated with total monthly car driving distance. Furthermore, males (compared to females) were more inclined to travel by active transportation modes, and persons that have always access to a car (compared to persons that do not have always access to a car) tended to travel less by active transportation modes. It also seems that monthly travel distances were explained by different sociodemographic factors for different trip purposes.

Concerning psychosocial factors, both total monthly car driving distance and total monthly active travel distance were related to perceived behavioural control for walking and cycling. The association was negative for car driving, but positive for active travel. Besides, it was found that total monthly active travel distance was negatively associated with perceived behavioural control for driving. Travel attitudes only played a statistically significant role in explaining total monthly car driving distance. More specifically, pro transit attitudes and anti-travel attitudes were negatively related to car driving. As such, some support has been found for the TPB, which posits that attitudes, subjective norms, and perceived behavioural control underlie (travel) behaviour (Ajzen, 1991; Gardner & Abraham, 2008; Hunecke et al., 2010; Pronello & Gaborieau, 2018). Note that subjective norms have not been addressed in this study, however.

After adding neighbourhood preferences to the models including travel attitudes and perceived behavioural control, model fit improved for both total monthly car driving distance and total monthly active travel distance. Total monthly car driving distance was positively associated with a preference for a clean, green, and quiet suburban neighbourhood, while total monthly active travel distance was negatively related to a preference for a car-oriented neighbourhood and a preference for a neighbourhood near work location, previous home, and social contacts. Besides, it was found that a neighbourhood preference for easy access to a good public transport service and a proper school or university was negatively related to both total monthly car driving distance and total monthly active travel distance. Next to this, it seems that monthly travel distances were explained by different psychosocial factors for different trip purposes, which is in line with previous studies. According to Zailani et al. (2016), the importance of attitudes and perceived behavioural control in explaining the intention to use public transport was different for different trip purposes. Besides, Ramezani et al. (2018a; 2018b) distinguished between work and non-work trips and found that sustainable mode choice for both types of trips was explained by different travel attitudes and neighbourhood preferences.

5.2. Practical implications

As psychosocial factors were found to play a substantial role in explaining travel behaviour, soft measures addressing psychosocial factors seem promising. According to Santos et al. (2010), behavioural campaigns can be quite cost-effective in fostering sustainable mobility. Attitudes and perceived behavioural control are malleable to some extent, implying these factors can be altered by means of policy interventions (Ajzen, 1991; Petty & Cacioppo, 1986). Whether this is also the case for neighbourhood preferences has not been researched so far. Nonetheless, it can be expected that neighbourhood preferences are not set in stone either, since preferences for a residential environment might at least partly be associated with attitudes towards travel. After all, it seems likely that someone with pro sustainable travel attitudes also has a preference for a neighbourhood that is conducive to cycling, walking, and public transport (Ramezani et al., 2020).

In order to reduce car driving, there is a need for enhancing pro transit attitudes and perceived behavioural control for walking and cycling. Beirao & Sarsfield Cabral (2007) proposed providing information about (the advantages of) public transport and improving service levels, in order to improve the image of public transport and as such enhance pro transit attitudes. Reliability, travel speed, and frequency are considered most important attributes of public transport by Dutch users of public transport and therefore require substantial policy efforts (Mouwen, 2015), especially in rural areas where service levels of public transport are typically rather low (Velaga et al., 2012). Perceived behavioural control for walking and cycling can potentially be increased by extending the infrastructural network for pedestrians and cyclists, implementing separated cycling paths, providing street lightning, and improving bicycle parking (Dill et al., 2014; Wall et al., 2007). However, it should be noted that the effects of these hard measures on travel attitudes and perceived behavioural control have not been assessed in this study.

Next to increasing perceived behavioural control for walking and cycling, there also is a need for decreasing perceived behavioural control for driving, in order to stimulate active travel. The latter could be established by limiting car access to streets and increasing the costs of driving, for instance by introducing road pricing. Eliasson et al. (2009) found that the number of car trips in the region of Stockholm, Sweden decreased after introducing road pricing. Around half of the evicted car trips were replaced by public transport (ibid). This could indicate a slight increase in active travel as well, as people might walk or cycle to the train or bus stop. While limiting car access to streets and increasing the costs of driving might lead to issues concerning justice, it can be argued that these policy interventions actually lead to more just outcomes (Creutzig et al., 2020; Schweitzer & Taylor, 2008).

However, whether an intervention is just ultimately depends on (1) one's perspective and (2) who is affected by the intervention and in which way (positive or negative). Therefore, limiting car access and increasing the costs of driving should not be pursued without considering how this affects different people in different ways and whether that is just.

Despite the potential of soft measures concerning travel attitudes and perceived behavioural control, it should be noted that habits can impede sustained behavioural change (Bamberg & Schmidt, 2003; Verplanken et al., 1997; 1998). However, there is also literature that suggests modal choice can largely be considered a reasoned decision, which means that a decision results from a process of reasoning and deliberation (Bamberg et al., 2002; 2003). This is especially the case after travel related circumstances have changed, such as travel costs and residential location (ibid).

Behavioural campaigns are likely more effective in bringing about behavioural change when these are targeted at certain subgroups in the population (Santos et al., 2010). Following Zhu & Lee (2009), the findings concerning the role of sociodemographic factors on travel behaviour can be used to determine which persons should be targeted by behavioural campaigns to foster sustainable mobility. In line with previous studies (Ramezani et al., 2020; Snellen et al., 2005), young, full-time employed persons with a high income, and/or living alone with or without children tend to travel relatively much by car and should therefore be targeted by behavioural campaigns. However, policy makers should be aware that different sociodemographic factors play a role in explaining travel behaviour for different trip purposes.

Given that built environment factors only seem to play a minor role in explaining travel behaviour, policy interventions aimed at altering the built environment do not seem to be cost-effective in reducing car driving (Stevens, 2017). Although not considered in this study, the built environment might have a substantial indirect effect on travel behaviour, however. More specifically, the built environment can affect travel behaviour by altering travel attitudes and perceived behavioural control (De Vos et al., 2021; Dill et al., 2014; Ramezani et al., 2021b). Therefore, policies aiming at dense, diverse, and attractive environments where destinations are nearby can help foster sustainable mobility (Dill et al., 2014; Ramezani et al., 2018a; 2018b).

5.3. Reflection and research agenda

As the sample used in this study was only slightly representative for the adult population in the north of the Netherlands (Table 12) and sample size was relatively small (N=192), the findings of this study only provided a first glimpse at the antecedents of travel behaviour amongst adults in the provinces of Drenthe, Friesland, and Groningen. Generalising the findings of this study to the adult population in the north of the Netherlands might therefore be a bridge too far. Nonetheless, the findings of this study were largely in line with previous studies, suggesting the findings are at least plausible and can be valuable for policy makers and researchers alike.

Although not necessarily representative, the sample was rather diverse with regard to age and education level. This can be considered an improvement over studies that use relatively uniform samples (e.g. Bamberg & Schmidt, 2003) in the sense that the sample provides a better reflection of the entire population. The holistic approach used in this study was an attempt to reflect the complexity of travel behaviour. After all, travel behaviour might be affected by built environment factors, sociodemographic factors, and psychosocial factors simultaneously (Cao et al., 2009; Cervero & Kockelman, 1997; Guan et al., 2020; Ramezani et al., 2018a; 2018b; 2020). Combining these factors in statistical analyses can therefore be considered a strength of this study.

Despite deliberate consideration of the research approach, there are some limitations to this study, however. First, sample size was relatively small (N=192) and participants have not been randomly selected, which might have had a negative impact on reliability of the findings and representativeness of the sample.

Second, only direct effects of built environment factors, sociodemographic factors, and psychosocial factors on travel behaviour have been assessed in this study, while indirect effects might also play a role in explaining travel behaviour, as explained in the previous section (De Vos et al., 2021; Dill et al., 2014; Ramezani et al., 2021b). Therefore, the role of built environment factors in explaining monthly car driving distance and monthly active travel distance might have been underestimated in this study. In order to take into account indirect effects, the use of structural equations modelling seems promising and has already been applied in travel behaviour research (e.g. Dill et al., 2014; Ramezani et al., 2021a; 2021b; Zailani et al., 2016).

Third, only a relatively small number of indicators of built environment factors have been used (i.e. 8) to assess the effect of the built environment on monthly car driving distance and monthly active travel distance. Obviously, this might also have caused an underestimation of the effect of built environment factors on travel behaviour. Therefore, future research should take into account a wider range of indicators regarding built environment factors, including availability of street lightning, sidewalks, and planting strips (Ramezani et al., 2018b). It should be noted that geographical data on the built environment is often scarce, however. Nonetheless, Geographic Information Systems (GIS) can help derive the right information from large datasets (Handy et al., 2002).

Fourth, accuracy of the analysed travel distances might have been rather low, as Euclidean travel distances (rather than real travel distances) had been calculated and respondents might not have reported all activity locations in the Maptionnaire survey. In order to improve the accuracy of the analysed travel distances, the use of GPS tracking devices seems useful, as illustrated by previous studies (e.g. Evenson et al., 2013; Plazier et al., 2017).

Fifth, travel was perceived as a derived demand in this study and therefore only trips with a specific destination have been considered. Contrary to the assumption that travel is a derived demand, there is evidence that people might also value travelling for its own sake (Mokhtarian & Salomon, 2001). In line with this, Steg (2004) found that car use is not only related to instrumental motives (i.e. getting from A to B as efficiently), but also to motives relating to status, identity, and affection. The use of GPS tracking devices might also overcome this problem, as both instrumental and non-instrumental trips can be tracked.

While this study was rather quantitative in nature and therefore helps to understand travel behaviour on an aggregate level, this hardly tells anything about the experiences with and motives for travel behaviour by a particular individual. As shown by previous studies (e.g. Meijering & Weitkamp, 2016; Plazier et al., 2017), a mixed methods approach can help make sense of quantitative data by collecting additional qualitative data, for example by means of in-depth interviews. As such, a mixed methods approach can improve our understanding of travel behaviour. Therefore, such an approach seems a promising avenue for future research.

Future research should also aim at understanding the role of population density in explaining travel behaviour in different contexts. Besides, the role of network design (i.e. number of turns and angular changes between streets) in mediating the role of intersection density on travel behaviour should also be addressed. It is also interesting to study the extent of residential dissonance in the study area and its effects on travel behaviour.

Despite a number of limitations, this study can already be considered an important step towards a holistic understanding of travel behaviour amongst residents in the north of the Netherlands. By combining built environment factors, sociodemographic factors, and psychosocial factors to explain travel behaviour, this study contributed to the academic debate concerning travel behaviour and provided suggestions for policy practice as well, in order to foster sustainable mobility.

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Appendices

Appendix 1: Maptionnaire survey

Link to survey: https://new.maptionnaire.com/q/4r6h3ymx2vf7
Note that the survey is also available in Dutch.

Information about yourself: Sociodemographic characteristics

1. Gender:
   a. Female
   b. Male
   c. Other
2. Age in years: [answer]
3. Highest level of completed education:
   a. Basic education
   b. Upper secondary education
   c. Undergraduate level (Bachelor's degree)
   d. Graduate level (Master's degree)
   e. Postgraduate level (PhD)
4. Employment status:
   a. Full-time employed (≥ 36 hours a week)
   b. Part-time employed (< 36 hours a week)
   c. Unemployed
   d. Student
   e. Retired
   f. Other
5. Household type:
   a. Living alone
   b. Living alone with child/children
   c. Living with a partner
   d. Living with a partner and child/children
   e. Living with my parents/caretakers
   f. Several people with separate budgets
   g. Other
6. Total monthly available income (after taxation) of your household (you and your partner, if you have one):
   a. Less than €1.500 per month
   b. €1.500-3.000 per month
   c. €3.000-4.500 per month
   d. €4.500-6.000 per month
   e. €6.000-7.500 per month
   f. €7.500-9.000 per month
   g. More than €9.000 per month
   h. I don't want to tell

7. Do you have physical limitations that prevent you from certain transport modes? If yes, please choose the modes of transportation you can't use because of that limitation.
    a. No
    b. Walking
    c. Cycling
    d. Public transport
    e. Driving
    f. Other
8. Do you own an 'OV-chipkaart'?
    a. Yes, most of the time I travel at full fare.
    b. Yes, most of the time I can travel at a reduced travel fare.
    c. Yes, most of the time I can travel for free.
    d. No, I need to buy a separate ticket if I want to travel by public transport.
9. Do you own a bicycle?
    a. Yes
    b. No
10. Do you have a driving license (for a car)?
    a. Yes
    b. No
11. What is the number of cars in your household? [answer]
12. Do you have access to a car that you can drive yourself?
    a. Yes, I always have access to a car.
    b. Yes, I have access to a car multiple times a week.
    c. Yes, I have access to a car occasionally.
    d. No, I do not have access to a car.

Your opinions about travel: Travel attitudes
Please indicate the extent to which you agree or disagree with the following statements.
Strongly disagree (1) - Strongly agree (5)

1. I find it annoying to have variation in my daily travel time.
2. Transit fare affects my choice of daily travel by public transport.
3. I find it annoying to wait for another travel mode while travelling.
4. Fuel price and/or price of parking affects my choice of daily travel by car.
5. I prefer to walk rather than drive whenever possible.
6. I like to be able to rest or read while travelling.
7. Vehicles should be taxed on the basis of the amount of pollution they produce.
8. I could manage pretty well with one fewer car (or with no car).
9. I prefer to cycle rather than drive whenever possible.
10. I prefer to organize my errands so that I make as few trips as possible.
11. I try to limit my driving to help improve air quality.
12. I prefer driving to other modes of transportation.
13. I prefer to take public transportation than drive whenever possible.
14. I like to avoid queues and congestion while travelling.
15. Changing how people travel is a great way to improve the environment.

Travel behaviour

Please click on the purple field below to be directed to the map where you can mark your current home location. Zoom in to place the marker correctly. If you do not want to reveal your exact home location, please locate the marker at the nearest intersection. [home location on map]

Now, I would like to ask you to think about a typical week in your everyday life. Please mark on the map your common destinations in your surroundings to which you travel during a typical week, considering COVID-19 regulations have become more relaxed. Zoom in to place the marker correctly. Please map all kinds of destinations that apply. You may report more than one place under each category if you wish. [activity location(s) on map]

1. When the weather is nice, what is the primary mode of transportation you usually use to visit this place?
    a. Walking
    b. Bicycle
    c. Public transport
    d. Car (as driver)
    e. Car (as passenger)
    f. Other? Please specify:
2. How often do you travel to this place?
    a. (Almost) everyday
    b. A couple of times per week
    c. Once a week
    d. A couple of times per month
    e. Once a month

Your perceived ability to take a certain transport mode: Perceived behavioural control

Please move the slider to indicate your perceived ability to drive a car/walk/cycle/take public transport for daily travel from home.

1. Driving a car for daily travel from home would be:
   Completely impossible (1) - Completely possible (5)
2. Driving a car for daily travel from home would be:
   Very hard (1) - Very easy (5)
3. It is completely up to me if I drive a car for daily travel from home.
   Strongly disagree (1) - Strongly agree (5)
4. Walking for daily travel from home would be:
   Completely impossible (1) - Completely possible (5)
5. Walking for daily travel from home would be:
   Very hard (1) - Very easy (5)
6. It is completely up to me if I walk for daily travel from home.
   Strongly disagree (1) - Strongly agree (5)
7. Cycling for daily travel from home would be:
   Completely impossible (1) - Completely possible (5)

8. Cycling for daily travel from home would be:
   Very hard (1) - Very easy (5)
9. It is completely up to me if I cycle for daily travel from home.
   Strongly disagree (1) - Strongly agree (5)
10. Taking public transport for daily travel from home would be:
    Completely impossible (1) - Completely possible (5)
11. Taking public transport for daily travel from home would be:
    Very hard (1) - Very easy (5)
12. It is completely up to me if I take public transport for daily travel from home.
    Strongly disagree (1) - Strongly agree (5)

Important neighbourhood features: Neighbourhood preferences
Please indicate how important the following characteristics were when you were choosing your current neighbourhood.
Not at all important (1) - Very important (5)

1. Easy to walk and/or cycle in the neighbourhood
2. Facilities such as a community center or places to spend free time available nearby
3. Good street lightning
4. Tree lined street
5. Spacious housing available
6. Easy access to school or university
7. Clean neighbourhood
8. Parks and green spaces nearby
9. Safe to walk around at night
10. Easy access to highway network or main road
11. Outdoor recreation opportunities nearby
12. Easy access to a good public transport service
13. Neighbourhood school quality (for my children)
14. Proximity to work location
15. Easy access to (city) center
16. Easy access to a district shopping center
17. Safe and convenient to walk and bike for errands
18. Proximity to my previous home
19. Proximity to my social contacts
20. Local shops within walking distance (e.g. grocery store)
21. Affordability
22. Quiet neighbourhood
23. Low level of car traffic on neighbourhood streets
24. Easy to find parking for residents
25. Diverse neighbours in terms of cultural backgrounds and age
26. Economic situation of neighbours similar to my level
27. Attractive appearance of neighbourhood
28. Lots of interaction among neighbours
29. Many people out and about within the neighbourhood

Appendix 2: Flyer used for recruitment

ONDERZOEKSPROJECT DAGELIJKS REISGEDRAG

Beste bewoner,

Mijn naam is Jacko en ik ben student aan de Rijksuniversiteit Groningen. Momenteel werk ik aan mijn afstudeerproject/scriptie over het dagelijks reisgedrag van volwassenen in Noord-Nederland.

U zou mij erg helpen door mijn enquête in te vullen via deze link: https://new.maptionnaire.com/q/4r6h3ymx2vf7. Het is ook mogelijk om hiervoor de onderstaande QR-code te scannen.

Het invullen kost ongeveer 10 tot 15 minuten. Als waardering verloot ik onder de deelnemers twee VVV-waardebonnen ter waarde van €25.

Alvast bedankt!

Appendix 3: Visited places for recruitment

Province of Drenthe

1. Beilen
2. Dwingeloo
3. Meppel
4. Hoogeveen
5. Coevorden
6. Aalden
7. Emmen
8. Borger
9. Assen
10. Annen

Province of Friesland

1. Drachten
2. Oosterwolde
3. Heerenveen
4. Sloten
5. Leeuwarden
6. Harlingen
7. Dokkum
8. Anjum
9. Holwerd
10. Hurdegaryp

Province of Groningen

1. Warffum
2. Roodeschool
3. Delfzijl
4. Siddeburen
5. Grootegast
6. Oldehove
7. Middelstum
8. Hoogezand
9. Stadskanaal
10. Winschoten