VU UNIVERSITY AMSTERDAM

THE IMPACT OF INCOME AND SERVICE DENSITY ON TRAVEL SUSTAINABLE MODE CHOICE FOR NON-COMMUTING DAILY TRIPS

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Abstract

The increasing need for urban sustainability has brought attention to the factors influencing travel mode choices, particularly for non-commuting trips, as this area has been less extensively studied and remains relatively underexplored. This research investigates the socio-economic influences on travel behavior, focusing on how income and service density impact the selection of sustainable travel modes, which include walking and cycling. Understanding these influences is vital for informing urban planning strategies aimed at promoting sustainable travel behaviors and creating more livable, environmentally friendly cities. A quantitative observational cross-sectional study is conducted using data from Statistics Netherlands and SafeGraph's Places database, utilizing moderated logistic regression analysis. The study found that income did not have a significant impact on the choice of travel modes. However, service density significantly influenced the likelihood of choosing sustainable travel modes, and a significant interaction between income and service density was also observed. These findings highlight the significant role of service density in travel decisions while indicating that income does not significantly influence this relationship. The study acknowledges limitations, such as the exclusion of physical health data of respondents and suggests further research into other aspects of travel behavior like travel time. The insights gained can aid in promoting sustainable travel and improving urban planning, particularly in the context of the 15-minute city concept.

Keywords: sustainable travel, income, service density, non-commuting trips, urban planning

1. Introduction

Following the 2015 Paris Climate Change Conference, the adoption of the low-carbon city as a policy agenda has amplified the focus on urban sustainability more than ever before (Moreno et al., 2021). Transportation within urban areas has become a widely discussed and researched topic, as it is currently the fastest-growing sector worldwide in terms of energy consumption, with cities accounting for the majority of this growth (Yan and Crookes, 2009). The environmental and climatic impact is most substantial from transportation modes that rely on fossil fuels such as gasoline or diesel, leading to CO_2 emissions and contributing to global warming. Additionally, traffic and transportation result in the emission of nitrogen oxides and particulate matter, which are key contributors to the reduction of air quality at the living level.

The emergence of the 15-minute city concept has further highlighted the importance of urban sustainability. The concept of the 15-minute city strives to establish self-sufficient neighborhoods by decentralizing urban functions and services, encompassing essential aspects as living, working, commerce, healthcare, education, and entertainment (Bocca, 2021). This concept, gaining increasing attention through numerous academic papers and news articles, underscores the need for a thorough examination of its fundamental principles, its contributions to sustainability, and the potential barriers to its implementation. Given these challenges, there is substantial potential for improvement in travel behavior, necessitating further research to find viable solutions.

This study builds upon previous research on travel behavior in urban areas, intentionally incorporating income as a variable because it significantly influences travel behavior (Zegras & Srinivasan, 2007). Besides, it is important to gain more insight into socio-economic differences, such as income, between population groups in different urban areas. Casarin et al. (2023), for example, emphasize in their research the importance of mapping socio-economic differences to address accessibility to services. They argue that socio-economic status significantly influences individuals' ability to reach essential services, and recognizing these disparities is essential for designing equitable urban policies. By considering socio-economic factors, urban planners can ensure that all residents, regardless of income, have access to sustainable transportation options and services, thereby promoting inclusivity and reducing inequality in urban areas. This understanding directly informs the investigation into how income affects travel mode, particularly the choice between sustainable and non-sustainable options, and the role that location and the availability of services play in these decisions.

Despite the extensive research conducted on travel patterns and times for commuting trips (Engelfriet & Koomen, 2018; Lin et al., 2015; Schwanen et al., 2001), this study focuses on a gap in the literature by investigating travel behavior for non-commuting daily trips. This research is scientifically relevant as it aims to provide insights into non-commuting travel behavior. The focus on non-commuting daily trips is driven by the fact that urban service facilities play a crucial role in the public's everyday quality of life, and the equitable distribution of these facilities is a major concern for urban planners (Shi et al., 2020). By addressing this gap, the study contributes to a more comprehensive understanding of urban travel behavior, which is essential for developing effective urban planning strategies.

This research is also of societal importance as it can provide insights for improving livability in densely populated areas and aid in further developing and implementing the 15-minute city concept. By examining non-commuting travel behavior, the study aims to inform urban planning practices that enhance the equitable distribution of urban service facilities, thereby contributing to the creation of more sustainable and livable urban environments.

The insights gained from this study and previous research can provide guidelines for promoting sustainable travel behavior for non-commuting daily trips in the Netherlands. The research question is formulated as follows:

"*To what extent does income affect the type of travel mode (sustainable versus non-sustainable) for non-commuting daily trips, and what role plays the density of services?"*

2. Theoretical framework

2.1 Socio-economic effect: income

Multiple studies have found that income has a substantial effect on travel behavior, often leading to less sustainable transportation choices as income increases. Schwanen et al. (2001) demonstrate that higher incomes reduce the likelihood of walking and cycling for all types of trips. Additionally, increased income diminishes the use of public transport for shopping and commuting, though there is a rise in public transport usage for leisure activities among higher-income households. Similarly, Zegras and Srinivasan (2007) provide a detailed analysis comparing Santiago, Chile, and Chengdu, China, showing evidence that higher household motorization rates, especially among wealthier residents, result in greater car usage. This trend persists despite Santiago's relatively high public transport share, with both middle- and high-income residents preferring cars over more sustainable options like walking and bus travel. Furthermore, Barff et al. (1982) highlight the strong correlation between income and car ownership, which negatively impacts sustainable travel modes in a sense that when the income increases more people have their own car for transportation. Collectively, these studies suggest that as income rises, individuals are more likely to choose private vehicles over sustainable transport modes. Consequently, this leads to the following hypothesis:

H1 (main effect 1): Higher income leads to less sustainable travel compared to lower income.

2.2 Service density

A considerable amount of research has found that urban density significantly influences travel patterns, with higher densities generally promoting more sustainable travel behaviors. Engelfriet and Koomen (2018) highlight the impact of urban density on travel patterns in cities across the United States and Europe. Urban density or population density, commonly defined as the number of persons per neighborhood acre, affects travel mode choices by encouraging non-auto modes of transportation such as walking, biking, and public transit, especially in high-density areas defined as having over 50 persons per neighborhood acre (Lewis, 2018).

To enhance the accuracy of the analysis, this study will focus on not only population density but also on service density. Service density is critical in understanding travel behavior, particularly for non-commuting trips, as it directly impacts the availability and accessibility of urban public service facilities that offer public goods and services (Shi et al., 2020). The service density approach aims to provide a more comprehensive understanding of how urban form influences travel patterns by considering the density of services rather than just urban density.

The study by Lewis (2018) aligns with and builds upon the work of Engelfriet and Koomen (2018), concluding that as density increases from rural to urban core levels, auto miles and trips decrease, while walk and transit miles and trips increase. This suggests that sufficient density encourages individuals to choose for more sustainable travel modes. Further supporting this, Frank and Pivo (1994), Stevens (2016) and Ewing and Cervero (2010) demonstrate a significant relationship between density and travel mode choice. Their studies show that higher densities are associated with increased walking and transit use, while lower densities favor single-occupant vehicle use. This reinforces the idea that higher densities promote non-automobile travel modes, contributing to more sustainable urban travel patterns.

Overall, the evidence indicates that as the density in an area increases, individuals are more likely to choose sustainable travel modes. By focusing on service density, this study aims to capture a crucial aspect of urban form that influences travel behavior, providing insights that align with findings from several studies (Ewing & Cervero, 2010; Frank & Pivo., 1994; Lewis, 2018; Stevens, 2016). Therefore, the hypothesis is formulated as follows:

H2: a higher level of service density in an urban area leads to more sustainable transport than in urban areas with a lower service density.

Building on this, individuals with higher incomes in less densely populated areas are more likely to choose less sustainable travel options. This phenomenon is supported by Lin et al. (2015), who found that higher incomes are positively correlated with increased reliance on private cars, particularly in areas with lower population density where the distance to work is typically longer. This preference for less sustainable travel modes among higher-income individuals can be attributed to the fact that they often have more specialized jobs located farther from their homes. The interaction between income and density exacerbates the preference for private vehicles, further reducing the sustainability of travel modes. Thus, Lin et al. (2015) highlight the significant impact of income and density on travel behavior, underscoring the need for policies that address these factors to promote more sustainable travel options.

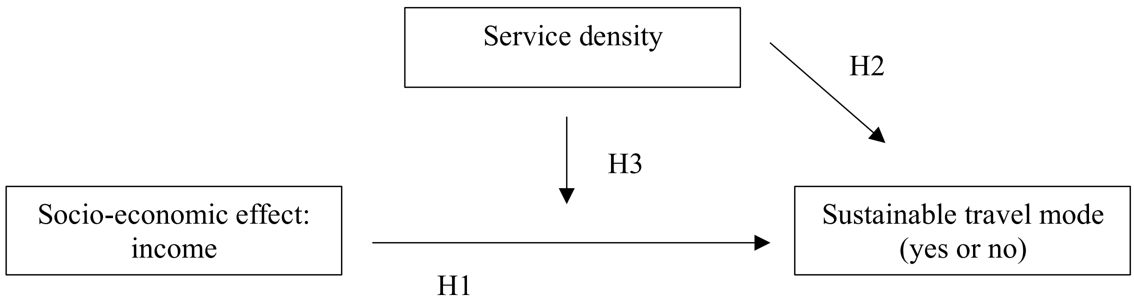
H3 (interaction-effect): a higher income leads to less sustainable travel than a lower income and this effect becomes weaker when the density is higher.

2.3 Summary and conceptual model

To summarize, higher incomes generally lead to less sustainable travel behavior, such as less walking and cycling and more car use, while high service density tends to promote sustainable transport options like public transport and walking. Studies show that higher incomes in urban areas like Santiago lead to increased car use, whereas higher density is associated with more use of public transport and walking. The interaction between income and density indicates that the negative effect of higher income on sustainable travel behavior is less pronounced in densely populated areas. This leads to the hypotheses that higher income leads to less sustainable travel (H1), higher service density leads to more sustainable transport (H2), and the negative effect of income on sustainable transport decreases with higher density (H3).

Figure 1

Expected effect of socio-economic factors (income) on sustainable travel mode, with the service density as a moderator.



3. Data and methodology

3.1 Design

This study is a quantitative, observational cross-sectional research employing numerical data for statistical analyses. The analysis is based on a single time point, thus measuring the relationships between variables at a specific moment.

3.2 Data

The data used for this study is sourced from Statistics Netherlands (CBS), which conducts an annual survey on the daily travel behavior of residents of the Netherlands aged six and older and data about the density at postcode level. This annual survey, called "Onderweg in Nederland" (ODiN), measures various aspects such as travel duration, purpose, and mode of transportation per trip. (Centraal Bureau voor de Statistiek, 2023). Additionally, demographic data and other relevant factors, such as, education, socio-economic status, and car ownership, are collected.

The sample used for the baseline study of ODiN is a stratified two-stage model, with the target population drawn from the Basisregistratie Personen (BRP). In the first stage, municipalities or sub-municipalities within each region were systematically selected with probabilities proportional to their population sizes. The number of individuals to be sampled from each selected municipality or sub-municipality was also determined in this stage. The second stage involved a simple random sample of individuals within the selected municipalities or sub-municipalities, with sample sizes as determined in the first stage. For the baseline study in 2022, a total of 61.953 individuals were approached. Table 1 shows the demographic characteristics of the respondents. In addition, table 2 illustrates the trip purposes of all observed trips, focusing exclusively on non-working activities.

Furthermore, another data source was utilized to obtain useful information regarding services and their locations. The data on service density was sourced from SafeGraph's Places database. Table 3 provides information on the average amount of accessible different services within a 15-minute walking or cycling time, calculated at 100 meter grid level in postcode 4 level residential neighborhoods.

Table 1 *Demographic characteristics of the respondents*

Variables	Descriptions	N/Mean	%/S.D.
Sociodemographics			
Gender	Male (0)	31498	50.8
	Female (1)	30455	49.2
Age	6 - 11 (1)	3494	5.6
	12 - 14 (2)	2282	3.7
	15 - 17 (3)	1960	3.2
	18 - 19 (4)	1766	2.9
	20 - 24 (5)	3790	6.1
	25 - 29 (6)	4172	6.7
	30 - 34 (7)	4436	7.2
	35 - 39 (8)	3685	5.9
	40 - 44 (9)	3787	6.1
	45 - 49 (10)	3852	6.2
	50 - 54 (11)	4882	7.9
	55 - 59 (12)	4099	6.6
	60 - 64 (13)	4261	6.9
	65 - 69 (14)	4247	6.9
	70 - 74 (15)	3656	5.9
	75 - 79 (16)	4300	6.9
	80 and older (17)	3284	5.3
Income	Low income (1)	9102	14.7
	Medium income (2)	23720	38.3
	High income (3)	27501	44.4
Education level	No education completed (0)	943	1.5
	Primary education (1)	2561	4.1
	Lower vocational education/VMBO (2)	9839	15.9
	Secondary vocational education (3)	17179	27.7
	Higher vocational education, university (4)	23891	38.6
	Other education (5)	1764	2.8
	Not asked; younger than 15 years (6)	5776	9.3
Car ownership	No (0)	9701	15.7
	Yes (1)	52252	84.3

Note N = 61953

Table 2 *Trip purpose: The five most frequent non-working daily activities (amenity-related) are shopping, leisure, sports, education, and service/care*

Trip purpose	Number (%)
Shopping	39388 (19.7)
Leisure	17858 (8.9)
Sports (including hobbies)	16321 (8.2)
Education	14278 (7.1)
Service/care	6244 (3.1)
To/form work	29809 (14.9)

Note N = 200054

Table 3 *Service density: average amount of accessible different services within 15 minute's walking/cycling time, calculated at 100 meter grid level in postcode 4 level residential neighborhoods*

Type of service	Cycling	Walking
Service personal care	43.6	3.7
Education	1.8	0.1
Sports	30.7	2.2
Recreation	3.1	0.2
Shopping grocery	40.8	3.7

Note N = 4052

3.3 Research area

In the ODiN study, only daily movements within Dutch territory are examined. Movements that occur entirely abroad are not included in the dataset. However, cross-border movements are included. For these movements, the trip distance and travel duration are partially attributed to the Netherlands and partially to the foreign country. In publications on the ODiN results, the foreign portion of these movements is excluded from the analysis (Centraal Bureau voor de Statistiek, 2023).

3.4 Model structure

In this study, a moderated logistic regression analysis is conducted to investigate the effect of income on the choice of sustainable travel modes, with service density considered as a moderator. This type of analysis allows us to examine the relationship between a continuous independent variable *income* and a dichotomous dependent variable *sustainable travel mode* (non-sustainable = 0 vs. sustainable travel mode = 1), while accounting for the moderating effect of *service density*. Whereby the unit of observation daily trips is.

In the initial phase of data cleaning, missing values and outliers were identified and addressed. Cases with missing data were thoroughly examined, and those with significant missing information were removed from the dataset to ensure the integrity of the analysis. The Frequencies function in SPSS was used for this purpose. By implementing these steps, the dataset was ensured to be clean, accurate, and ready for subsequent analysis.

Since the dependent variable is dichotomous, logistic regression is suitable for modeling the relationship between income and travel mode choice. The model examines the likelihood that an individual chooses a sustainable travel mode based on their income for a daily activity trip. To analyze the moderating effect of service density, an interaction term between income and service density is added to the logistic regression model. This helps to understand whether and how the effect of income on travel mode choice for daily trips depends on the level of service density.

The logistic regression model with an interaction term is specified as:

$$Logit\left(P(Y=1, trip\ type\ i)\right) = \beta 0 + \beta 1(Income) + \beta 2(Service\ Density\ of\ trip\ type\ i) + \beta 3(Income * Service\ Density) + \beta 4(Age) + \beta 5(Gender) + \beta 6(Education) + \beta 7(Car\ Ownership) + \beta 8(Population\ Density) + \beta 9(Urbanity) + \beta 10(Municipality\ Size)$$

Where trip type *i* represents Personal care trips; Education trips; Sports trips; Recreation trips; Shopping trips.

3.5 Control variables

According to previous research, various factors may influence the relationships examined in this study. Therefore, the following variables will be included as control variables in the analyses: age, gender and highest level of education completed. These demographic factors are likely to influence the relationship between independent variables and the dependent variable, thereby helping to control for potential confounding effects and providing a more accurate analysis of the data. Besides demographic factors, research by Frank and Pivo (1994) has shown that higher densities are associated with lower car ownership rates. Therefore, car ownership (no car = 0 versus car owned = 1) may potentially influence the relations. The size of a city is a fundamental aspect of urban structure, serving as the foundation for numerous other urban form measurements and grounded in the standard economic theory (Engelfriet & Koomen, 2018; Mills, 1972). For this reason, the size of a city measured in inhabitants is included as a control variable. Additionally, population density is included as a control variable in this study because it is the most used metric in research examining the effect of urban form on travel behavior and times (Engelfriet & Koomen, 2018). Population density is defined as the average number of residents per square kilometer at postcode 4 level. Lastly, urbanity is also included in the analysis because the level of urbanization of the residential environment remains an important determinant of travel behavior (Schwanen et al, 2001). Urbanity is categorized from non-urbanized to highly urbanized.

3.6 Independent variables

The variables relevant for measuring the main effects as formulated in the three hypotheses will be discussed in more detail below.

3.6.1 Income

To illustrate the socio-economic differences between population groups, *income* is a crucial factor. At the individual level, income is an important determinant of travel options (Engelfriet & Koomen, 2018). In this study, using data from Onderweg in Nederland (ODiN), income is measured as the disposable income of the Dutch population. Disposable income is calculated by deducting paid income transfers, insurance premiums, health insurance, and taxes on income and wealth. Additionally, disposable income is measured and divided into deciles within the ODiN dataset to facilitate a detailed analysis of income distribution and its impact on travel behavior across different income groups.

In this study, the variable of income is categorized into 3 classes, namely low, medium and high income. The criteria for these categories are defined as follows: the low-income category includes the income groups to 30%, the medium-income category covers income groups ranging from 30% to 70%, and the high-income category includes all income groups above 70%. This approach is adopted based on the research design conducted by (Zegras & Srinivasan, 2007), which demonstrated the effectiveness of such categorization in analyzing travel behavior. Categorizing income into 3 scales aims to capture a more nuanced understanding of the relationship between income levels and travel behavior.

To investigate the effect of the socio-economic factor income on the choice of sustainable travel mode, a logistic regression analysis is conducted, with income as the independent variable. This analysis utilized the binary logistic regression procedure in SPSS, with income included.

3.6.2 Service density

The moderator in this study is the variable service density, which is a crucial aspect for the creation of sustainable communities that rely less on cars (Lewis, 2018). In this study, this variable is manipulated to refer specifically to service density. By measuring service density instead of general population density, a clearer understanding of the effect density has on non-commuting trips can be achieved. Still, to provide a clearer understanding of population density, figure 2 maps out the population density in the Netherlands at the postcode 4 level. The service density approach allows for a more precise analysis of how the availability and proximity of services influence travel behavior. The service density used in this study is the sum of the accessible different services of education, shops, personal care, recreation and sports within 15-minute walking and cycling calculated at 100 meter grid level in the respondents' postcode 4 level residential neighborhoods (figure 3). Furthermore, the appendix provides separate maps of services of education, shops, personal care, recreation and sports within 15-minute walking and cycling time.

To measure the effect of service density on sustainable travel mode, a logistic regression analysis is conducted, with service density as the independent variable. This analysis utilized the binary logistic regression procedure in SPSS.

Figure 2 *Population density in the Netherlands: persons/km2 at the postcode level*

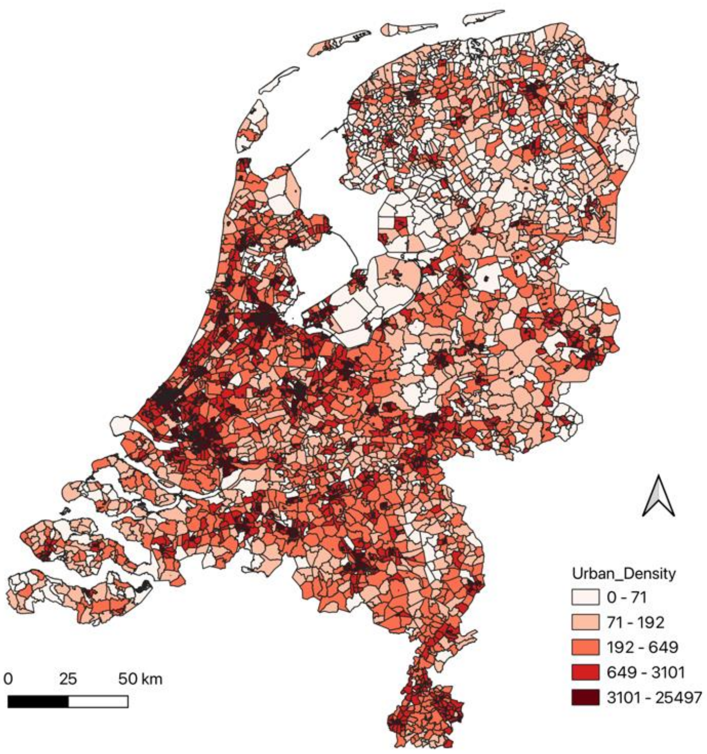
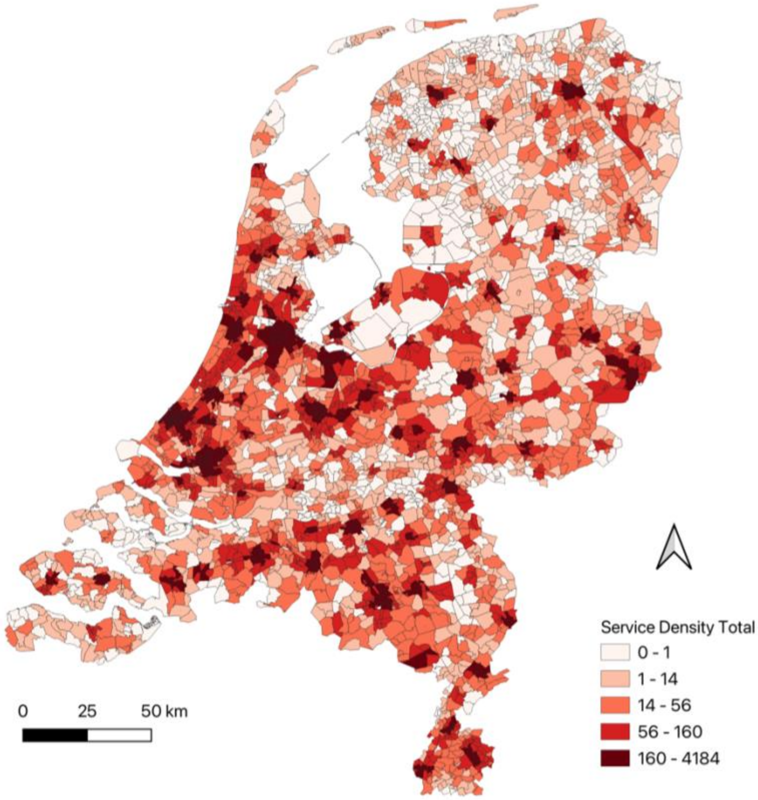


Figure 3 *Service density in the Netherlands: average amount of accessible services within a 15-minute travel time in the respondents' postcode 4 level residential neighborhoods.*



<u>3.7 Dependent variable</u>

3.7.1 Sustainable travel mode

Travel behavior is an essential aspect of the focus on new urban designs, specifically the efficiency of urban designs concerning commuting distances, time, and travel mode (Schwanen et al., 2001). This study will specifically focus on the type of transport chosen for daily non-commuting trips. Non-commuting trips include trips that are not work-related but trips for shopping, personal care, sports, recreation and education.

To test the moderation effect of service density on the relationship between income and sustainable travel mode, a logistic regression analysis with an interaction term is performed ins SPSS. Travel mode is measured as a dichotomous variable, where 0 represents non-sustainable travel modes and 1 represents sustainable modes.

4. Results

To investigate the impact of the variables from the previously formulated hypothesis, a logistic regression analysis will be conducted for H1, H2, and H3. The predictor variables income categorized into three groups, service density, and the interaction between these variables will be tested a priori to verify that there is no violation of the assumption of linearity of the logit. Before conducting the analyses, a correlation check will be performed.

4.1 Correlation

Before the analyses of the main effects can be conducted, this study examined the correlation between the variables: urbanity, municipality size, gender, age, car ownership, education, income, travel mode, population density, service density and all types of service density separately. This examination is made to determine how these variables are related to each other. The analysis aims to provide insight into the interrelationships among the variables.

It is important to note that the decision was made to include only the density of accessible different services within 15 minutes' cycling time, rather than within 15 minutes' walking time, in the correlation analysis. This choice was based on the strong correlation observed between these two types of sustainable transport across all types of services. A possible explanation for this strong correlation is that a 15-minute cycling area encompasses a 15-minute walking area.

The correlation matrix in Table 4 displays the Pearson correlation coefficients between the relevant variables.

Table 4 *Correlation matrix*

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Urbanity	1														
2. Municipality Size	-0.75**	1													
3. Gender	0.00	0.00	1												
4. Age	0.09**	-0.12**	-0.05**	1											
5. Education	-0.06**	0.06**	0.00	-0.42**	1										
6. Pop Density	-0.63**	0.64**	0.00	-0.11**	0.04**	1									
7. Service Density Total	-0.46**	0.53**	0.01**	-0.08**	0.05**	0.71**	1								
8. Car Ownership	0.25**	-0.27**	-0.03**	0.09**	0.03**	-0.33**	-0.31**	1							
9. Income	0.09**	-0.10**	-0.03**	-0.18**	0.18**	-0.14**	-0.11**	0.35**	1						
10. Travel mode	-0.07**	0.05**	0.04**	-0.02**	0.10**	0.07**	0.08**	-0.09**	-0.03**	1					
11. Density Shopping	-0.44**	0.50**	0.01**	-0.08**	0.04**	0.69**	0.97**	-0.30**	-0.12**	0.08**	1				
12. Density Recreation	-0.42**	0.51**	0.01**	-0.08**	0.05**	0.67**	0.91**	-0.31**	-0.11**	0.07**	0.88**	1			
13. Density Sports	-0.45**	0.52**	0.01**	-0.08**	0.05**	0.69**	0.98**	-0.30**	-0.10**	0.08**	0.93**	0.90**	1		
14. Density Education	-0.34**	0.42**	0.01**	-0.07**	0.04**	0.53**	0.87**	-0.28**	-0.11**	0.07**	0.84**	0.79**	0.85**	1	
15. Density Personal Care	-0.47**	0.54**	0.01**	-0.08**	0.05**	0.72**	0.98**	-0.31**	-0.11**	0.08**	0.92**	0.87**	0.97**	0.84**	1

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

*. Correlation is significant at the 0.05 level (2-tailed)

The results indicate a very strong negative correlation between urbanity and municipality size, $r(200054) = -0.745$, $p < 0.001$. Additionally, population density and service density total are strongly positively correlated, $r(200054) = 0.712$, $p < .001$.

A strong correlation is also found between density personal care and population density, $r(200054) = 0.719$, $p < .001$. This correlation is expected, as the variable density of personal care services is a component of the total service density. It was a deliberate decision to include all specific types of services besides the overall service density in the analysis because it is relevant to identify the specific types of services in a given area rather than categorizing all of them under the generic label of 'service'. Therefore, the analysis does not focus on the strong correlation between these different types of services, as they are highly relevant and important to include in the analysis.

In conclusion, it is important to highlight the variables with the strongest correlation with each other because a high correlation between variables can indicate a potential problem with multicollinearity. So based on the correlation matrix (table 4), urbanity is included in the analysis as control variable instead of municipality size. This decision is based on previous research showing that urbanity is an important determinant of travel behavior.

Lastly, population density is excluded from the analysis as a control variable because of the strong correlations.

4.2 Results of H1

The predictor variable, income, in the logistic regression analysis was not found to contribute significantly to the model. The unstandardized beta weight for the constant was *B* = 0.037, *SE* = 0.044, *Wald* = 0.689, $p = 0.406$. The unstandardized beta weight for the predictor variable was *B* = -0.016, *SE* = 0.011, *Wald* = 2.322, $p = 0.128$. The estimated odds ratio favored no significant change (*Exp(B)* = 0.984, 95% CI [0.964, 1.005]) for choosing a sustainable travel mode for every one level increase of income. See the appendix for the variables in the equation (table 7).

These results indicate that income does not significantly predict the likelihood of choosing a sustainable travel mode. Thus hypothesis 1 is not accepted.

4.3 Results of H2

The predictor variable, service density total, in the logistic regression analysis was found to contribute significantly to the model. The unstandardized beta weight for the constant was *B* = -0.261, *SE* = 0.042, *Wald* = 39.679, $p < 0.001$. The unstandardized beta weight for the predictor variable was *B* = 0.00035, *SE* = 0.000, *Wald* = 334.997, $p < 0.001$. The estimated odds ratio indicated an increase of 0.035% (*Exp*(*B*) = 1.000, 95% CI [1.000, 1.000]) for choosing a sustainable travel mode for every one unit increase of service density.

These results indicate that the service density total is a significant predictor of choosing a sustainable or non-sustainable travel mode. Specifically, as the service density increases, the likelihood of selecting a sustainable travel mode increases. For each unit increase of the services, the odds of choosing a sustainable travel mode increase by approximately 0.035%. Although the effect size is small, it nonetheless indicates a positive effect. It suggests that a higher service density ensures that individuals are more inclined to choose sustainable travel modes. Thus, hypothesis 2 is accepted

Additionally, logistic regression analyses were conducted separately for the density of services of education, shops, personal care, recreation, and sports within a 15-minute walking and cycling. This analysis deliberately examines each type of service separately, as the hypothesis specifically tests only for services. Therefore, it is relevant to gain more detailed information on this aspect. Table 5 provides the results of the regression of each model. The appendix provides the variables in the equation table of the regression of all six models.

In the logistic regression analysis, personal care density was found to contribute significantly to the model. The unstandardized beta weight for the constant was *B* = -0.872, *p*

< 0.001. The unstandardized beta weight for the predictor variable was $B = 0.00127$, $p < 0.001$. These results indicate that for each unit increase of personal care services, the odds of choosing a sustainable travel mode increase by approximately 0.127%. Although the effect size is small, it nonetheless indicates a positive effect. It suggests that a higher personal care service density ensures that individuals are more inclined to choose sustainable travel modes.

Education density was found to contribute significantly to the model. The unstandardized beta weight for the constant was $B = -0.358$, $p = 0.001$. The unstandardized beta weight for the predictor variable was $B = 0.004$, $p = 0.036$. These results indicate that for each unit increase in education services, the odds of choosing a sustainable travel mode increase by approximately 0.4%. It suggests that a higher education service density ensures that individuals are more inclined to choose sustainable travel modes.

Sports density was found to contribute significantly to the model. The unstandardized beta weight for the constant was $B = 0.940$, $p < 0.001$. The unstandardized beta weight for the predictor variable was $B = 0.00133$, $p < 0.001$. These results indicate that for each unit increase in sports services, the odds of choosing a sustainable travel mode increase by approximately 0.133%. It suggests that a higher sports service density ensures that individuals are more inclined to choose sustainable travel modes.

Recreation density was found to contribute significantly to the model. The unstandardized beta weight for the constant was $B = -0.586$, $p < 0.001$. The unstandardized beta weight for the predictor variable was $B = 0.011$, $p < 0.001$. These results indicate that for each unit increase in recreation services, the odds of choosing a sustainable travel mode increase by approximately 1.1%. It suggests that a higher sports service density ensures that individuals are more inclined to choose sustainable travel modes.

Shopping density was found to contribute significantly to the model. The unstandardized beta weight for the constant was $B = 0.191$, $p = 0.008$. The unstandardized beta weight for the predictor variable was $B = 0.0017$, $p < 0.001$. These results indicate that for each unit increase in shopping services, the odds of choosing a sustainable travel mode increase by approximately 0.17%. It suggests that a higher shopping service density ensures that individuals are more inclined to choose sustainable travel modes, although this effect is small.

In conclusion, the results indicate that all types of services (models 1-6) significantly positively impact the choice of a sustainable travel mode.

Table 5 *Results of binary logit regression*

Predictor Variable	***Model 1*** All daily trips	***Model 2*** Personal care trips	***Model 3*** Education trips	***Model 4*** Sports trips	***Model 5*** Recreation trips	***Model 6*** Shopping trips
Constant	-0.261	-0.872***	-0.358**	0.940***	-0.586***	0.191**
Control variables						
Urbanity	-0.075***	-0.119***	-0.061***	-0.050**	-0.007	-0.134***
Age	0.001**	0.004**	-0.039***	-0.003**	-0.006***	0.007***
Gender	0.032*	0.180**	-0.090*	-0.020	0.003	0.145***
Education	0.194***	0.119***	0.286***	0.014	0.210***	0.102***
Car Ownership	-0.535***	-0.269***	0.134*	-0.678***	-0.323***	-0.998***
Type of service						
Service Density Total	0.00035***					
Density Personal care		0.00127***				
Density Education			0.004*			
Denisty Sports				0.00133***		
Density Recreation					0.011***	
Density Shopping						-0.0017***
Model performance						
Pseudo. R^2	0.060	0.038	0.228	0.036	0.069	0.092
Number of trips modeled (N)	93705	6236	14141	16263	17787	39278

*** 0.1 % level of significance. $p < 0.001$
** 1 % level of significance. $p < 0.01$
* 5 % level of significance. $p < 0.05$
· 0.1 level of significance. $P < 0.1$

4.4 Results of H3

The predictor variable, the interaction term of income and service density total, in the logistic regression analysis, was found to contribute significantly to the model. The unstandardized beta weight for the constant was *B* = -0.230, *SE* = 0.041, *Wald* = 30.606, $p < 0.001$. The unstandardized beta weight for the interaction term was *B* = 0.00017, *SE* = 0.000, *Wald* = 354.507, $p < 0.001$. The estimated odds ratio indicated an increase of 0.017% (*Exp*(*B*) = 1.000, 95% CI [1.000, 1.000]) for choosing a sustainable travel mode for every one unit increase of the interaction term. The power of the explanatory model was assessed using the Nagelkerke R^2, which indicated that approximately 6% of the variance in the choice of a sustainable travel mode was explained by the model (table 6).

These results indicate that the interaction term of income and service density total is a significant predictor of choosing a sustainable or non-sustainable travel mode. Specifically, as the interaction term increases, the likelihood of selecting a sustainable travel mode increases. For each level increase of the interaction term, the odds of choosing a sustainable travel mode increase by approximately 0.017%. Although the effect size is small, it nonetheless indicates a positive effect. It suggests that individuals with higher incomes and in more dense areas are more inclined to choose for sustainable travel options. Thus, hypothesis 3 is accepted

Table 6 *Variables in the Equation*

								95% C.I.for EXP(B)	
		B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Step 1[a]	Urbanity	-.073	.006	136.342	1	.000	.930	.918	.941
	Age	.001	.000	15.782	1	.000	1.001	1.001	1.002
	Gender	.036	.014	7.180	1	.007	1.037	1.010	1.065
	Car ownership	-.590	.021	819.030	1	.000	.554	.532	.577
	Education	.193	.005	1580.843	1	.000	1.213	1.201	1.224
	Interaction Service density and income	.00017	.000	354.507	1	.000	1.000	1.000	1.000
	Constant	-.230	.041	30.606	1	.000	.795		

Note: *Nagelkerke* $R^2 = 0.060$ ($N = 91558$)

5. Conclusion

This study investigated the relationship between income and travel mode choice, distinguishing between sustainable and non-sustainable modes of travel for non-commuting trips. Additionally, the study examined the moderating role of service density. To explore this relationship, a quantitative, observational cross-sectional study was conducted, utilizing numerical data for statistical analyses.

Firstly, contrary to the expectations proposed in hypothesis 1, income did not have a significant effect on the chosen travel mode. Thus hypothesis 1 was rejected.

Secondly, consistent with hypothesis 2, the analysis revealed that service density positively impacts the travel mode choice. Although the effect size is small, it indicates a positive effect of higher density on an increased likelihood of choosing a sustainable travel mode. Additionally, all five different types of services separately had a significant positive effect on the chosen travel mode. Those results align with the predictions of hypothesis 2, thus leading to its acceptance.

Thirdly, consistent with hypothesis 3, the analysis revealed that the interaction effect of income and service density positively impacts the travel mode choice. Although the effect size is small, it indicates a positive effect of the interaction on an increased likelihood of choosing a sustainable travel mode. This result aligns with the prediction of hypothesis 3, thus leading to its acceptance.

In response to the research question: "To what extent does income affect the type of travel mode (sustainable versus non-sustainable) for non-commuting daily trips, and what role plays the density of services?" It can be concluded that income did not have a significant influence on the choice of sustainable travel modes for non-commuting daily trips. However, service density significantly impacted the choice of a sustainable travel mode, and the interaction effect between service density and income also has a small positive impact on sustainable travel mode.

6. Discussion

6.1 Theoretical and practical implications

This research, from a theoretical perspective, primarily offers insights in the form of suggestions for future studies. This study was designed by combining results from significant previous research on travel behavior and socio-economic differences. Although the study yielded non-significant results, it can serve as a foundation for future research, specifically in investigating travel behavior with a focus on the type of travel mode for non-commuting trips. Besides, this current study could invite exploration of other factors within travel behavior, such as travel time.

From a practical perspective, this study is relevant to the concept of the 15-minute city. The insights gained from this study, along with previous research, can provide guidance on improving and applying the 15-minute city concept to cities in the Netherlands. In the context of the 15-minute city, it is crucial to conduct further research on the accessibility and travel modes to different types of services, as services play an important role in the 15-minute city. This study has made an initial contribution to this field and encourages further research on this topic. However, this is an assumption based on current results and requires further validation through future research. Additionally, it can offer cities insights into becoming more sustainable by promoting sustainable travel modes and reducing emissions.

6.2 Limitations

However, these results should be interpreted with caution due to a couple of limitations of this study. A limitation of this study is that it captures only a single day's travel behavior. This approach may introduce bias, as the trips recorded on a particular day might not accurately reflect individuals' usual travel patterns. Travel behavior can vary from day to day due to various factors such as work schedules, weather conditions and personal preferences. Consequently, relying on single day data may not provide a comprehensive picture of typical travel behavior. Future research should consider collecting travel data over a more extended period to better capture the variability and patterns in travel behavior. This would help to provide a more accurate and reliable understanding of how people typically travel and make use of different services.

Secondly, the physical health of the respondents was not included in the analysis because this data was not available. Physical health can play a role in the choice of transport mode, as individuals with mobility issues may find it more appealing to choose driving over cycling or walking.

Thirdly, it would have been a relevant addition to the research to also focus on other aspects of travel behavior, such as travel time, in addition to travel mode, as applied in other studies (Schwanen et al., 2001; Zegras and Srinivasan, 2007; Lewis, 2018). Information on travel time could help to better understand the relationship between the type of mode and the time it takes to reach a destination, as well as provide an indication of the amount of emissions generated.

6.3 Future research directions

This study has several limitations. Firstly, it focused on the Netherlands as a whole. Given the significant differences between urban and rural areas within the country, future research could focus on specific cities. Investigating specific cities, as done by Engefriet and Koomen (2018) and Zegras and Srinivasan (2007), could provide valuable insights for future policy. The limitations of the study present both opportunities and challenges for future research. There was a significant but small effect of service density on the choice of travel mode. Future studies could explore the role of other underlying mechanisms and conditions that influence travel mode choice, such as whether individuals are physically able to access services by bicycle or walking. Additionally, it may be interesting for future research to include other travel modes, as walking and cycling are both slow modes of transportation, which might influence the outcomes. It could be relevant to analyze the probability of making a walking or cycling trip based on the availability of facilities within walking or cycling distance. Up to now, most research on travel behavior has not considered the potential for sustainability. Further research could therefore help to increase the use of sustainable travel modes in the future.

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Appendix

Figure 4 *Service personal care pedestrian: average amount of available services within 15 minute's walking time*

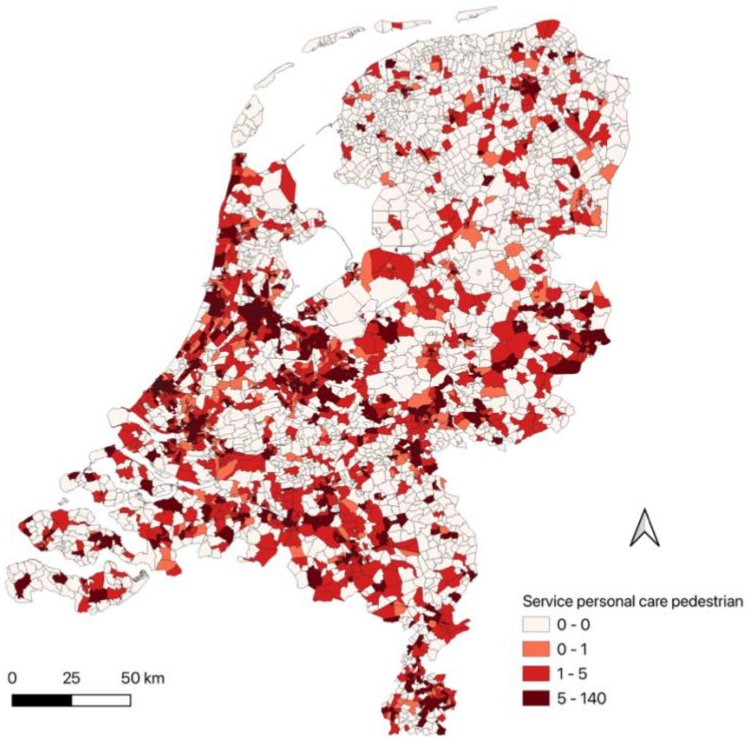

Figure 5 *Education pedestrian: average amount of available services within 15 minute's walking time*

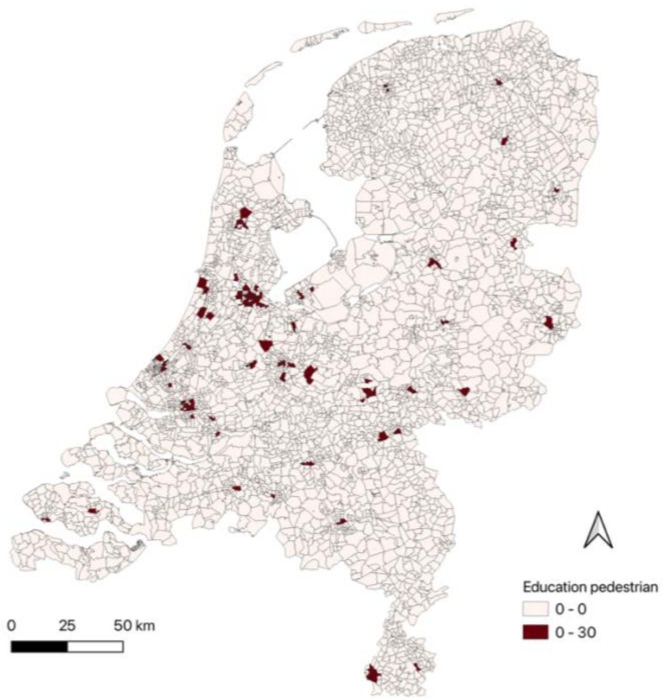

Figure 6 *Sports pedestrian: average amount of available services within 15 minute's walking time*

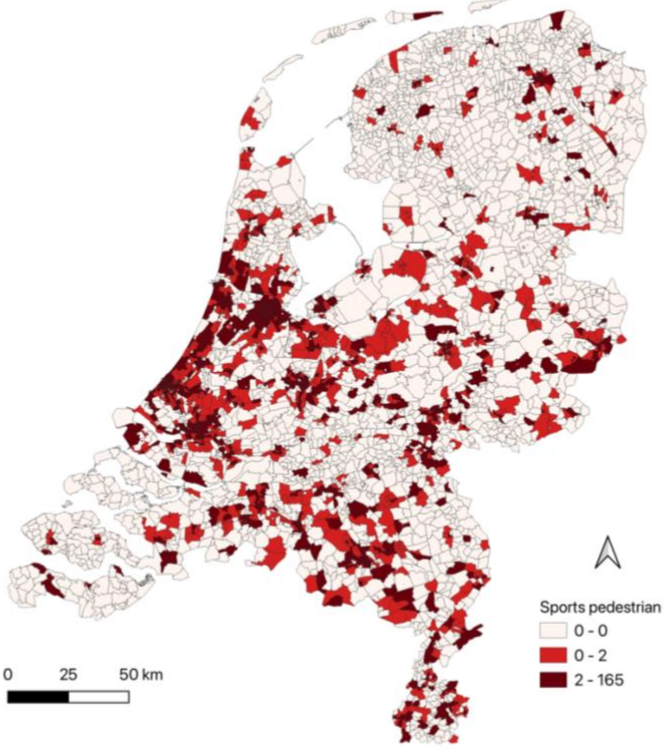

Figure 7 *Recreation pedestrian: average amount of available services within 15 minute's walking time*

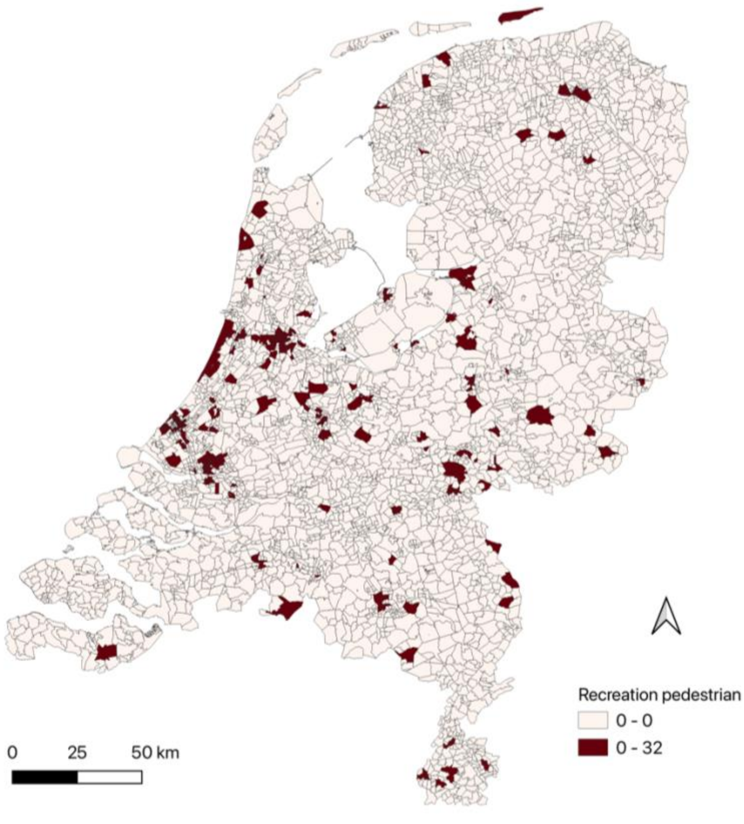

Figure 8 *Shopping grocery pedestrian: average amount of available services within 15 minute's walking time*

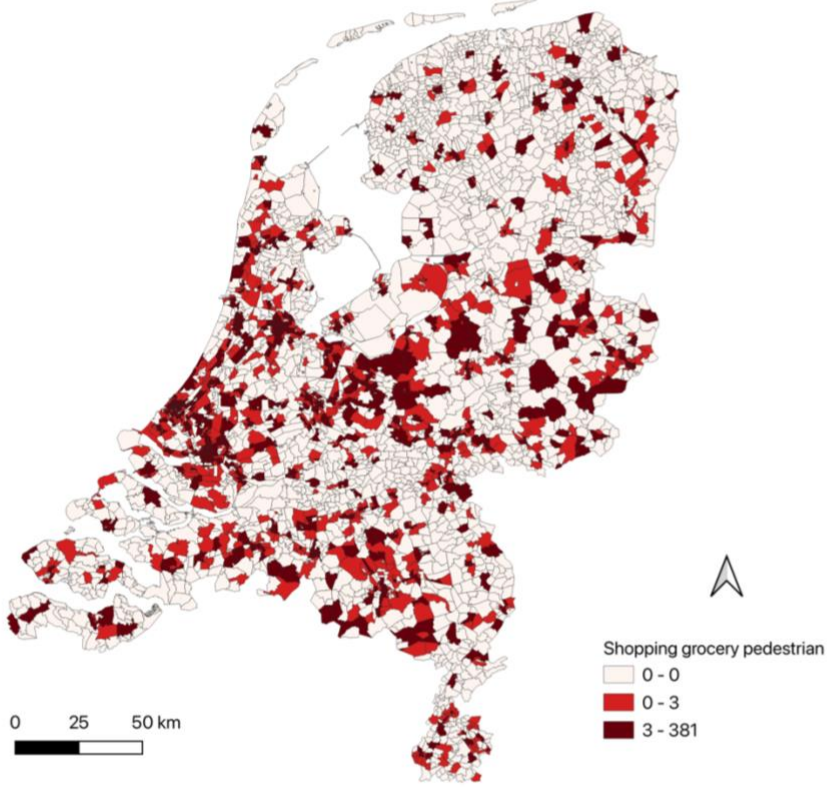

Figure 9 *Service personal care bicycle: average amount of available services within 15 minute's cycling time*

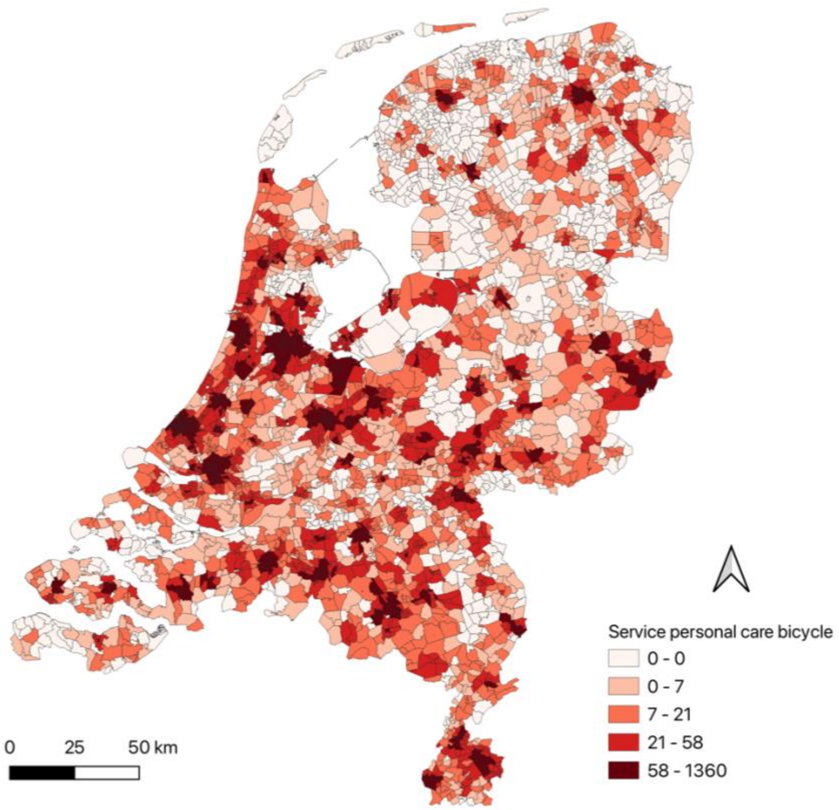

Figure ***10*** *Education bicycle: average amount of available services within 15 minute's cycling time*

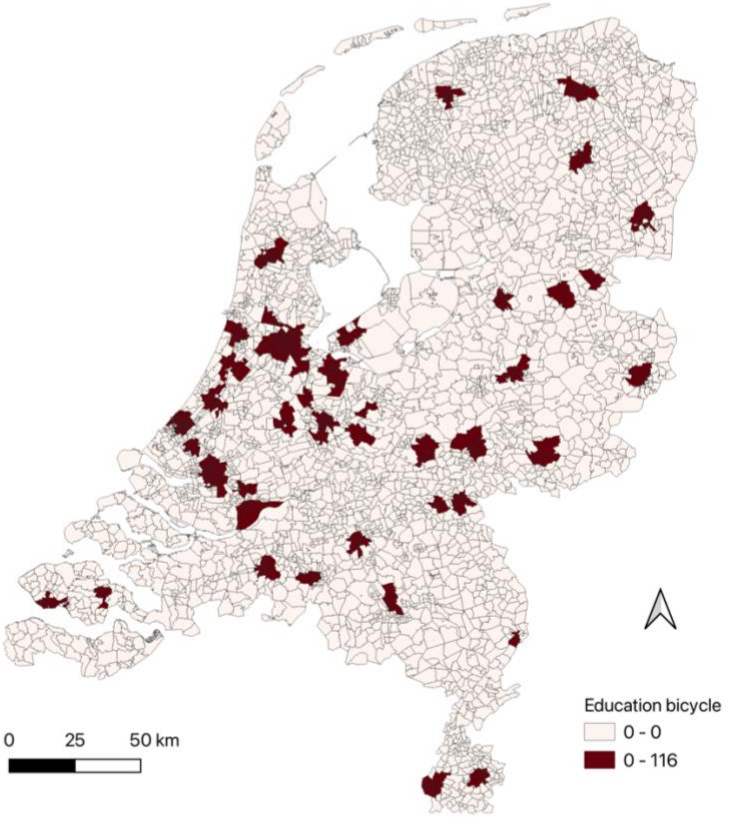

Figure 11 *Sports bicycle: average amount of available services within 15 minute's cycling time*

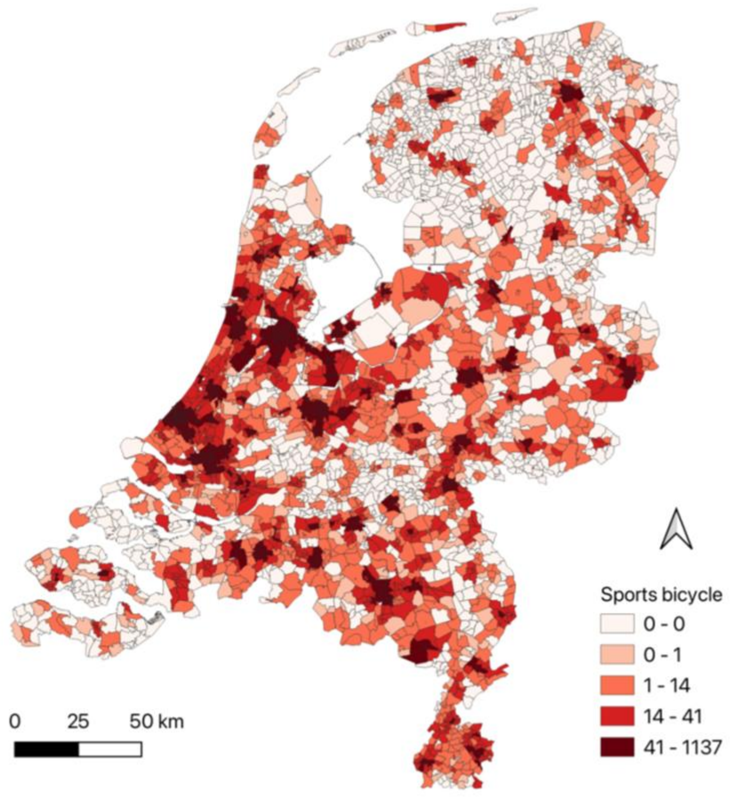

Figure 12 *Recreation bicycle: average amount of available services within 15 minute's cycling time*

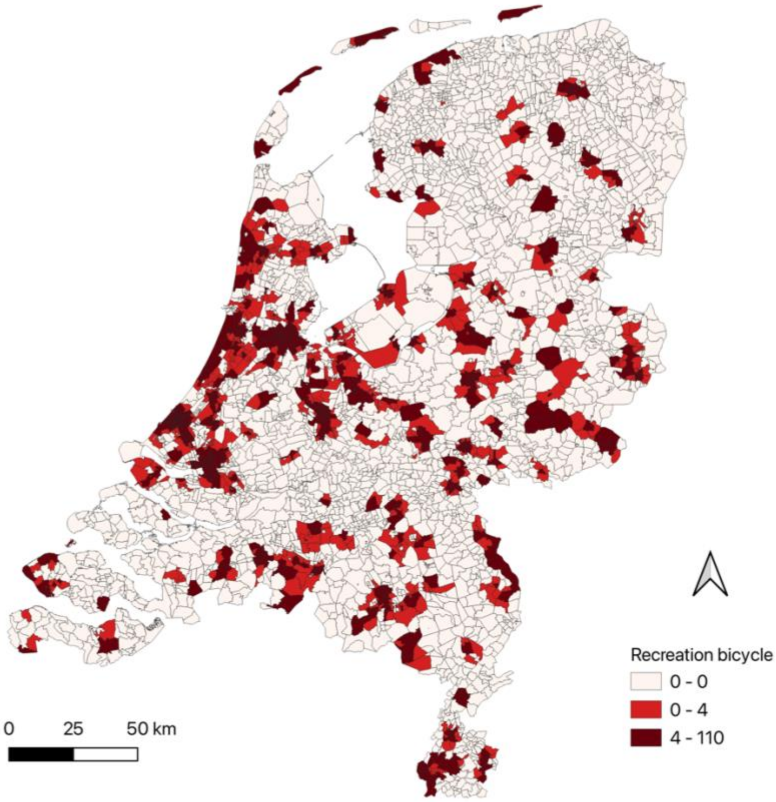

Figure 13 *Shopping grocery bicycle: average amount of available services within 15 minute's cycling time*

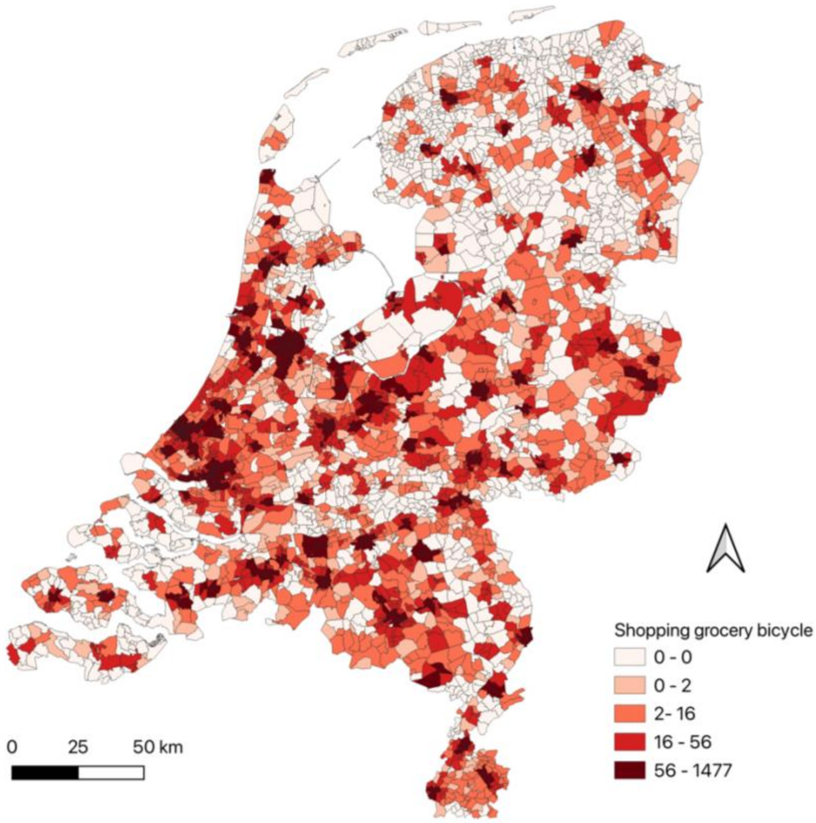

Table 7 *Variables in the Equation: hypothesis 1*

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Income	-.016	.011	2.322	1	.128	.984	.964	1.005
	Urbanity	-.125	.006	492.910	1	.000	.882	.873	.892
	Age	.001	.000	10.865	1	.001	1.001	1.000	1.002
	Gender	.035	.014	6.615	1	.010	1.035	1.008	1.063
	Car ownership	-.611	.022	776.050	1	.000	.543	.520	.567
	Education	.197	.005	1639.931	1	.000	1.217	1.206	1.229
	Constant	.037	.044	.689	1	.406	1.037		

Note: *Nagelkerke R^2* = 0.054 (*N* = 91558)

Table 8 *Binary logistic regression for model 1*
Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Urbanity	-.075	.006	145.470	1	.000	.928	.917	.939
	Age	.001	.000	11.705	1	.001	1.001	1.000	1.002
	Gender	.032	.013	5.668	1	.017	1.032	1.006	1.060
	Car ownership	-.535	.020	701.410	1	.000	.586	.563	.609
	Education	.194	.005	1632.149	1	.000	1.214	1.202	1.225
	Service density total	.00035	.000	334.997	1	.000	1.000	1.000	1.000
	Constant	-.261	.042	39.679	1	.000	.770		

Table 9 *Binary logistic regression for model 2*
Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Urbanity	-.119	.024	23.833	1	.000	.888	.847	.931
	Age	.004	.001	9.943	1	.002	1.004	1.002	1.007
	Gender	.180	.054	11.271	1	.001	1.197	1.078	1.329
	Car ownership	-.269	.076	12.549	1	.000	.764	.659	.887
	Education	.119	.023	26.308	1	.000	1.126	1.076	1.179
	Density personal care	.00127	.000	29.012	1	.000	1.001	1.001	1.002
	Constant	-.872	.180	23.520	1	.000	.418		

Table 10 *Binary logistic regression for model 3*
Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Urbanity	-.061	.016	14.593	1	.000	.941	.912	.971
	Age	-.039	.002	292.492	1	.000	.962	.958	.966
	Gender	-.090	.037	5.758	1	.016	.914	.850	.984
	Car ownership	.134	.053	6.297	1	.012	1.143	1.030	1.270
	Education	.286	.009	951.300	1	.000	1.331	1.307	1.356
	Density education	.004	.002	4.395	1	.036	1.004	1.000	1.007
	Constant	-.358	.106	11.327	1	.001	.699		

Table 11 *Binary logistic regression for model 4*

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Urbanity	-.050	.015	11.526	1	.001	.952	.925	.979
	Age	-.003	.001	11.383	1	.001	.997	.996	.999
	Gender	-.020	.032	.391	1	.532	.980	.920	1.044
	Car ownership	-.678	.056	145.063	1	.000	.507	.454	.567
	Education	.014	.011	1.501	1	.221	1.014	.992	1.036
	Density sports	.00133	.000	64.504	1	.000	1.001	1.001	1.002
	Constant	.940	.101	86.635	1	.000	2.561		

Table 12 *Binary logistic regression for model 5*

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Urbanity	-.007	.014	.250	1	.617	.993	.966	1.021
	Age	-.006	.001	60.052	1	.000	.994	.992	.995
	Gender	.003	.031	.013	1	.911	1.003	.944	1.067
	Car ownership	-.323	.045	51.931	1	.000	.724	.663	.791
	Education	.210	.012	317.722	1	.000	1.234	1.206	1.263
	Density recreation	.011	.001	93.684	1	.000	1.011	1.009	1.014
	Constant	-.586	.097	36.602	1	.000	.556		

Table 13 *Binary logistic regression for model 6*

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Urbanity	-.134	.010	188.839	1	.000	.875	.858	.892
	Age	.007	.001	140.032	1	.000	1.007	1.006	1.008
	Gender	.145	.021	46.987	1	.000	1.156	1.109	1.205
	Car ownership	-.998	.033	925.235	1	.000	.369	.346	.393
	Education	.102	.010	112.728	1	.000	1.107	1.087	1.128
	Density shopping	.00170	.000	274.547	1	.000	1.002	1.001	1.002
	Constant	.191	.072	7.101	1	.008	1.210		