Bachelor Thesis

Rijksuniversiteit Groningen

Faculty of spatial sciences

Study: Spatial Planning and Design

Leon Schoenmaker

Student number: S3491927

Supervisor: Farzaneh Bahrami

Date: 15-01-2020

# Moving towards a post-car society: The influence of street surface distributions on the choice of transportation mode

A case study comparing 3 Dutch provinces and their urban and rural regions

**Keywords:** Mode choice, automobile use, modal split, street surface distribution, surface split, infrastructure, transportation, car parking, parking space.

**Abstract**

This paper examines the interaction of the modal split and the street surface distribution in 3 Dutch provinces. Furthermore, the space occupied by public car parking is analyzed and put in perspective as this space is a valuable part of the urban environment. This analysis attempts, by using a Geographic Information Systems (GIS) analysis, to isolate the impact of the street space distribution on the modal split. By layering maps with different characteristics, specific parts of street surfaces are selected to analyze what a street surface split looks like of these provinces. Through comparing literature on this topic to the results of the GIS analysis, an indication of the influence of street surface on the actual choice in transportation mode is created. The mode choice of a population is complicated by many factors such as accessibility of modes, income variance, prices, preferences and habits. The results imply that the share of the street surface distribution is a relative representation of the modal split share of the same mode of transportation. This can be assumed because some noticeable statistics in the surface distributions are visible in the modal splits.

**Table of contents**


**Title page & abstract** _____ **p.1**

1. **Introduction** _____ **p. 2**
2. **Theoretical framework** _____ **p. 3-5**
3. **Conceptual model** _____ **p. 5-7**
4. **Hypothesis** _____ **p. 7**
5. **Methodology** _____ **p. 8-9**
6. **Results** _____ **p. 10-16**
    a. **Data analysis**
    b. **Comparison within provinces**
    c. **Comparison between provinces**
7. **Car-parking** _____ **p. 17-18**
8. **Conclusion** _____ **p. 18-19**
    a. **Reflection**
9. **References** _____ **p. 20-21**
10. **Appendix** _____ **p. 22**

## 1. Introduction

In the past decades, the use of the automobile has drastically increased and is still continuing to increase. At the rate that it is developing, stress on the environment is rising continuously (Freund, 2012; Delucchi and Kurani, 2014). More cars produce more (greenhouse gas) emission and require more space for the roads they drive on and the parking lots they require to be placed when not used. Space on earth is not infinite and can be used for more environmentally friendly or socially urgent purposes.

Hence, the automobility-system we live in nowadays is harming the planet (John Urry, 2004) and a transition to other central modes of transport is important for the future existence of the planet (John Urry, 2004; Freund, 2012). The future predictions of mode use say cars will stay the dominant mode of transportation for the upcoming decades. However, speeding up the transition away from the car by providing researches as these is important for the preservation of the environment. So, by asking: is the mode choice influenceable? by what/whom? And will this change the mass usage of the automobile (if yes, to what extent)? This research will contribute to this transition.

### 1.1 Relevance

This study is focusing on the influence of street space distribution on the choice of transportation mode of people in The Dutch Provinces Groningen, Noord-Holland and Limburg. A comparison will be made on how much of the street space is dedicated to a certain transportation mode and how much this mode is used (based on official statistics of the CBS (CBS Statline, no date). Finding out whether there is an existing relationship between these factors contributes to the transition away from a car based-society and can complement stimulation of using more sustainable modes of transportation than the car. Furthermore, it sets a fundament for further research.

Some Academics argue that mode choice is merely habitual, however, over the years the mode choice has shifted slightly but surely (Moser et al., 2019). So, only either habits have changed or there are other influencing factors at stake. This research can complement to the transition away from an automobility-system through answering its main research question. Which is:

- **What is the influence of street space distribution on the choice of transportation mode in urban and rural areas of the Dutch provinces Groningen, Noord-Holland and Limburg?**

Street space distribution is in this research understood as the available space dedicated to transportation and how this space is distributed between the different modes. A distinction will be made between automobile roads (which in some instances can also be used by busses), Pavement meant for pedestrians or other pedestrian paths, cycling lanes, and roads exclusively used by public transport. The space dedicated to outdoor car parking is taken into account in this research. This part of the surface analysis will include parking space alongside streets and other open spaces for car parking. Parking inside garages, private parking spots (as drive-ins) and private parking for companies will not be included. It will be analyzed to create awareness for the value of urban space and surface use.

The main question will be answered by answering the following sub-questions:

- How is street surface distributed among different modes of transportation (percentage-wise) in the provinces Groningen, Noord-Holland and Limburg?
- Is there an interrelation between street surface dedicated to a mode of transportation and the modal split of that mode in the selected case studies?
- How much space is dedicated to car parking and how can this be used differently?

## 2. Theoretical framework

### 2.1 Mode choice influencers

Moser et al. (2019) contradict the popular assumption that mode choices are made consciously by taking a rational decision. Moser et al. (2019) argue that the mode of transportation used by an individual is solely determined by habits. So, if people grew up using a certain type of transportation, they are most likely to use this in the future as well. Rojas López and Wong (2019) do agree with the statement that mode choice is habitual but they include a lot more factors in the PDMD (Process and Determinants of Mobility Decisions). They, for instance, mention that the built environment and accessibility of a mode of transport are a part of this process/choice too. Accessibility is partially financial status (whether you have the income to afford a car or bike), and partially infrastructural planning. Other scholars argue it is a matter of lifestyle that people developed. If people started to like using public transport or prefer being alone in the car, they would more often use these modes over other, maybe more sustainable modes (Prato, Halldórsdóttir and Nielsen, 2017). A lot of different theories about influencing factors of the mode choice, and is there a true or false? According to De Witte et. al. (2013), the epistemological basis of modal choice research is dependent on the practices and goals of the research teams, which will always complicate the discussion on what is leading for a modal choice.

### 2.2 Spatial determinants

A case study in South Africa tested a mixed land-use approach. The article states: "South Africa is burdened by the historic legacies and inherited Euclidean (Single-Use) zoning practices, resulting in the unequal access to public services, unequal benefits of economic spillovers and reduced mobility" (Geyer and Quin, 2019). This case study mentions mixing land-uses helps to create variety in mode choice as there is equal accessibility to it. "The study determined that significant increases in mixed-use development result in increased ethnic diversity, increased income equality indicative of mixed tenure, increased diversity of modal choices, decreased private motorized transportation and increased non-motorized transportation". This is a clear example that accessibility to a mode of transportation plays a role in the mode choice of an individual. Furthermore, if this accessibility is equal among a population, people are less drawn to private motorized transportation.

### 2.3 Importance of infrastructure

In the Netherlands, the bicycle is a commonly used and sustainable mode of transport. It is often used in combination with other modes of transport (Jonkeren O. *et al.*, 2019). However, if you look at statistics of other countries like the United States the bicycle is mostly not even mentioned in the modal split (Meyer and ITE (Institute of Transportation Engineers), 2016). This is mainly because of the street space distribution of the United States. In the Netherlands, the street space distribution must be well organized because of the size of the country and the awareness of sustainable transportation modes. However, still, most trips are made by car (*CBS Statline*, 2018) while this is the least sustainable mode choice regarding the number of gas emissions and the space it uses per person.

Many contradictions exist in the academic world as shown above. A lot of theories agree on the car being too intensively used and that the use of this particular mode should be reduced (‘Mode choice for VFR journeys’, 1998; John Urry, 2004; Freund, 2012; De Witte *et al.*, 2013; Delucchi and Kurani, 2014; Geyer and Quin, 2019). However, the discussion on how to do this is continuously growing. Some articles state that improving land use does not have enough influence on travel behavior but

that travel behavior should be influenced by the pricing of different modes of transportation (Zhang, 2004, 2006).

A difference in main modes of transportation in areas, regions or cities that also have a difference in street space distribution is probed in various previous researches (Zheng and Geroliminis, 2013; Geyer and Quin, 2019). For instance, if there are more cycling lanes available (in quantity/surface) people tend to feel safer to travel by bike as they do not have to cycle on the car roads (Freund, 2012) which is a motive to step off using a car for short trips and switch to a bicycle. One article is very specific in the battle between modes of transport for available urban space (Zheng and Geroliminis, 2013). This demand for space can be influenced by city planning, which is the organizer of the street space distribution. Zheng and Geroliminis (2013) state that the enormous demand for cars and car use caused a lot of urban space to be spent on highways or other busy car roads. This not only makes car use easier but also makes a cycling or walking environment more dangerous (Freund, 2012).

### 2.4 Dutch context

The mode choice is very versatile in the Netherlands (Jonkeren O. *et al.*, 2019). This is mainly because of the good availability of transportation modes. Everyone who has access to a car can also choose from a wide range of other modes like busses, trains (provided that the destination has a train station nearby), bike, or walking. However, this choice is not always explainable by only looking at its availability for individuals. The surface of urban areas and even rural areas are very valuable space. Especially in the Netherlands as it is a very densely populated country. So, space is scarce and usually, every piece of surface already has a function. A big occupier of urban space is parking spots for cars. The extent in which these parking spots are present influence the demand for public transport and thus have a great influence on moving away from the ease of taking the car (Stephen G. Ison and Corinne Mulley, 2014). Other researches set forth that non-optimized parking space in crowded urban areas can lead to vehicle circling which implies cars keep driving around in busy areas to find a parking spot (Mackowski, Bai and Ouyang, 2015). Optimizing the parking spaces can lead to a decrease in noise caused by these roads and more space left for other land uses.

This research will look into the effect of street space distribution on the choice in transportation mode of inhabitants of 3 selected Dutch provinces. Through analyzing different academic theories and models an insight is given in the process of a person making this choice (Rojas López and Wong, 2019). The car is the main mode of transportation globally because of demand and supply (John Urry, 2004). This research will try to determine whether the relationship between the surface dedicated to a mode of transportation and the modal split can alter the excessive car use. Furthermore, the surface area of parking spaces will be analyzed to create awareness amongst readers of this study on how much space is used for car parking and what policies can help improve this land use. Policies for parking space in the Netherlands are already present, but could possibly be more effective. Through academic literature, different methods of parking-regulation are compared and a critical

## 3. Concepts and Conceptual model

### 3.1 Leading concepts

One of the leading concepts for this research is the *modal split,* the modal split is the distribution of transportation modes within a given area (Williams, 1971). This is mainly indicated with percentages. E.g., the share of the car/automobile in the modal split could be 61% as it is the most used mode of transport worldwide. This modal split is often used to conceptualize a city as a cycling-friendly city or

a public transport oriented city (Vanoutrive, 2015). However, it is hard to determine the transportation characteristics of a city based on a modal split because the presence of a train station in a city can change the entire modal split.

Another concept that will be often referred to is *mode choice*. The mode choice is a decision of an individual on what mode of transportation he/she is going to use for a trip. This mode choice can vary for the distance of the trip, the weather, the number of people you travel with or (applicable in this study) the availability of a transportation mode (Dendrinos, 1976; 'Mode choice for VFR journeys', 1998).

*Street surface/space distribution* is mentioned in the introduction. This concept implies the dedication of space to a specific mode of transportation. So, cycle lanes, pavement for pedestrians, bus lines, car roads, highways (mixed-use). Many car roads can also be used by other modes of transport, think of a bicycle or busses, however, in this research, the focus lies on space that is focusing on its main user. That is pedestrians for pavements, cyclists for bicycle paths, etc.

Binding to this street surface distribution is the *surface split*. This term will be used for the percentual distribution of the street surface amongst the different modes of transport. The surface split stands for the total distribution, so the 100% of the street surface (knowing it consists of different parts).

### 3.2 Conceptual model

In the conceptual model of this research, we look at the street space distributed between these different modes that are available in the modal split of a city. The link between the space dedicated to a mode of transportation and the actual use of that mode of transport is examined. If there is an interrelation between these concepts a scenario is created where it is possible to test when this street surface/space distribution for a specific mode rises or falls if that mode is chosen less among its current users. So, the link between the modal split and the street space distribution can influence the choice-making process before the actual mode choice is made but also make people reconsider their mode choice (Rojas López and Wong, 2019). A new mode choice can lead to a new modal split of an area.

The different variables in this model are the street surface distribution and the modal split. These variables are analyzed in 3 different cases. A relationship between these variables is influencing the eventual mode choice in this model and thus the modal split. It becomes a cycle.

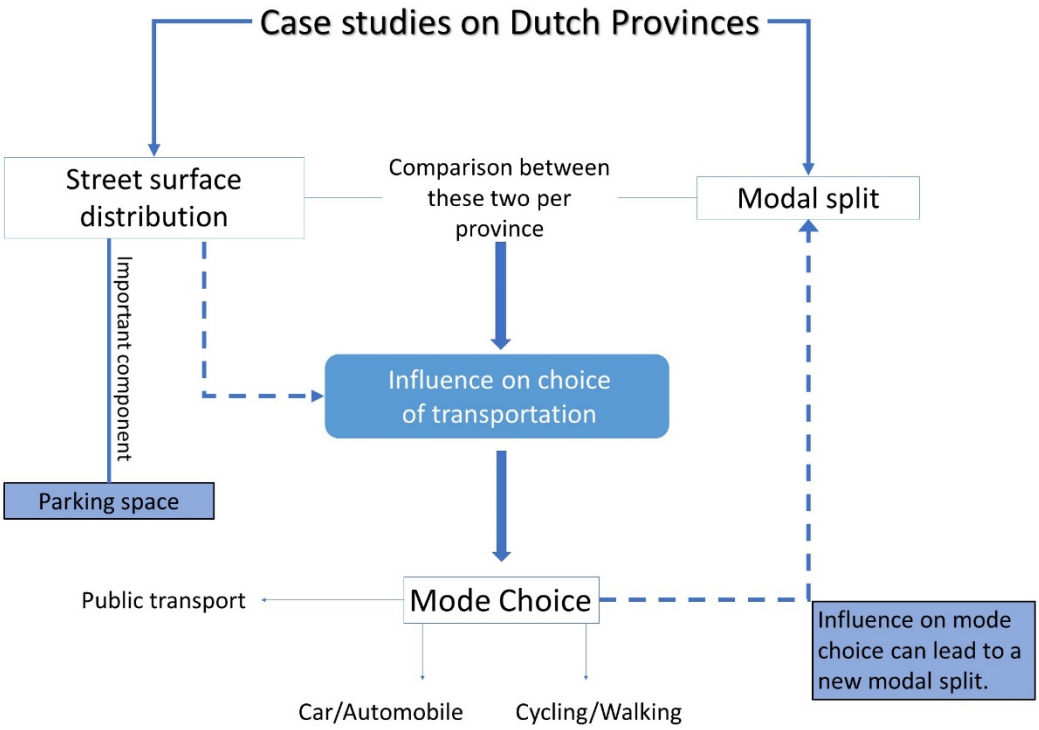


*Figure 1: the conceptual framework (source: Author)*

## 4. Hypothesis

The main research question of this study is: Does the street space distribution influence the choice of transportation mode in urban and rural areas of the Dutch provinces Groningen, Noord-Holland and Limburg?

Following the theories of the studies in the theoretical framework, a presumed outcome of this research is a relationship in street surface used for a specific mode and the actual use of the modes. The percentual split of the mode used will inevitably be different from the percentual split of the street surface due to all other factors that play a role, however, if there is an interrelation between the road surfaces dedicated to certain transportation modes and the actual mode choice, this research can complement to the transition away from an automobility-system. So, this study aims to prove whether there is an interrelation between street space distribution and mode choice of provincial residents. (Meyer and ITE (Institute of Transportation Engineers), 2016).

Other possible outcomes are that street space distribution is a demand and supply-bound mechanism and that the demand for the car caused (and changes) the percentage of road surface dedicated to cars(John Urry, 2004; Vanoutrive, 2015).

Furthermore, the space occupied by car parking spots will be analyzed to generate awareness amongst readers of this study how valuable parking space is. Parking space contributes to car use (Stephen G. Ison and Corinne Mulley, 2014), so by introducing more space-efficient parking systems, an attempt is made to raise awareness about this surface type and to create better uses for it.

## 5. Methodology

This research will make use of case studies to make a comparison between the street space distribution of three provinces from the Netherlands. The three provinces are Groningen, Noord-Holland and Limburg. They were selected on their difference in the location in the Netherlands which causes a difference in mode use between these provinces (*CBS Statline*, 2018) because they are located at different ranges from the Dutch business district (Randstad). Within these provinces, a distinction will also be made between urban and rural areas. To compare the street surface distribution, two components have to be looked into; the street/road/pavement surface that is dedicated to a specific mode of transportation and the modal split per case study. This means analyzing if the percentage of street space has an interrelation with the chosen transportation mode of an individual in the selected provinces. The distinction between urban and rural areas will be made on the municipal level. CBS statline (2018) provides an overview of the degree of urbanity of all the municipalities in the Netherlands. This is done through ranking the municipalities on a Likert scale (Batterton and Hale, 2017), ranging from “not urban” to “very much urban”. The lowest degree of urbanity on this scale will be referred to as rural in this research, and the highest degree will be referred to as urban. This scale is used because it is a very applicable classification urbanity in Dutch regions.

### 5.1 Strategy and Tools

The research strategy to answer the main question will be cartography, through a program as Geographic Information Systems (further referred to as GIS) accurate analyses can be made on the street surfaces of cities, even on pavement or bicycle lanes. GIS uses different layers of maps to analyze zones for specific characteristics. In the case of this research, it is possible to overlay the borders of the province or municipalities with the road parts and be able to select only the road parts within the selected borders. To make the process of the research more transparent and reproducible, a flowchart is included in the methodology (figure 2). This flowchart depicts the steps that are taken in the GIS analysis of this research. In this way, an attempt is made to generate an idea of how the results of this research have been obtained.

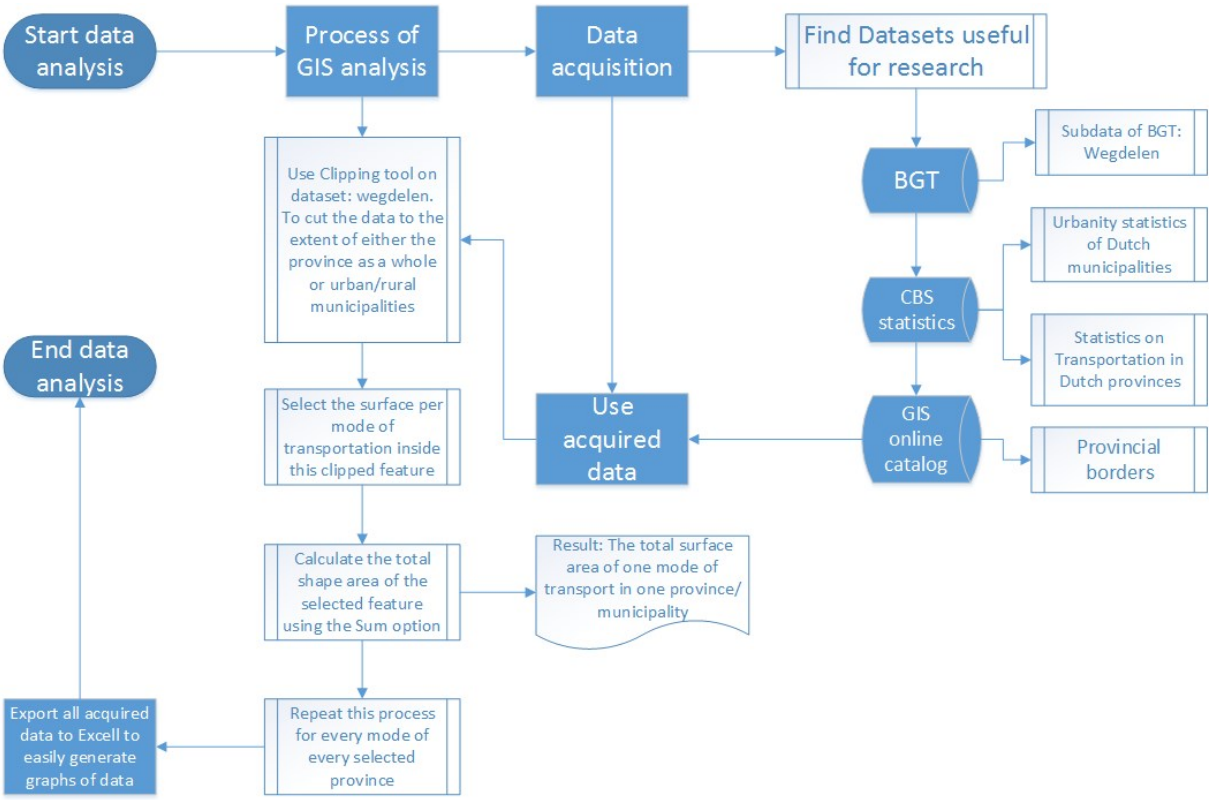


*Figure 2: Methodology flowchart (source: Author)*

The type of data that is going to be used will be mostly secondary data to create a set of primary data from the combination of these secondary data sources. Data files of map layers are available in the GIS online catalog.

The Basisregistratie Grootschalige Topografie (further referred to as BGT) is a dataset on almost every physical aspect of the Dutch landscape ranging from roads to households. A part of this BGT dataset named “wegdelen” (translated: road parts) will be used to analyze the surface dedicated to specific modes in the selected provinces. As this research focusses on the distribution of street space, train tracks and the surface that these tracks occupy are left out of the street analysis and will be categorized under ‘Other’ in the charts about modal splits and surface splits. Every part of the street surface will be measured individually and will be compared to the percentage of that mode share in the modal split. This will be done for the province as a whole, the urban municipalities and the rural municipalities. Data on the modal split for the case studies will be collected through the applicable statistical bureau for the Netherlands (for Dutch case studies that would be the Centraal Bureau Statistiek (*CBS Statline*, no date) as well as the degree of urbanity of the Dutch provinces. Data files of provincial and municipal borders are available in the GIS online catalog.

### 5.2 Ethical consideration

For this research, no further interaction is needed with the mode users from the selected provinces as the focus lies solely on the physical aspect of street space distributions. The statistics on the mode use that are applied in this research are secondary data which means they are gathered by the CBS (*CBS Statline*, 2018).

## 6. Results

### 6.1 Data analysis

To create a better understanding of the GIS research process that has been carried out, a visual representation of the research process is depicted in Figure 3 and 4. Figure 3 depicts the different scales that were used to create the urban, rural and provincial surface split. And figure 4 is a close up on the surface dedicated to cycling and walking in the center of Groningen. In figure 3 is depicted how this study came to the results in the graphs that are available in figure 5, 6 and 7. The road network of the province as a whole is analyzed and compared to the modal split (of the province). Afterwards, the urban and rural municipalities were also analyzed on their road surface per province.

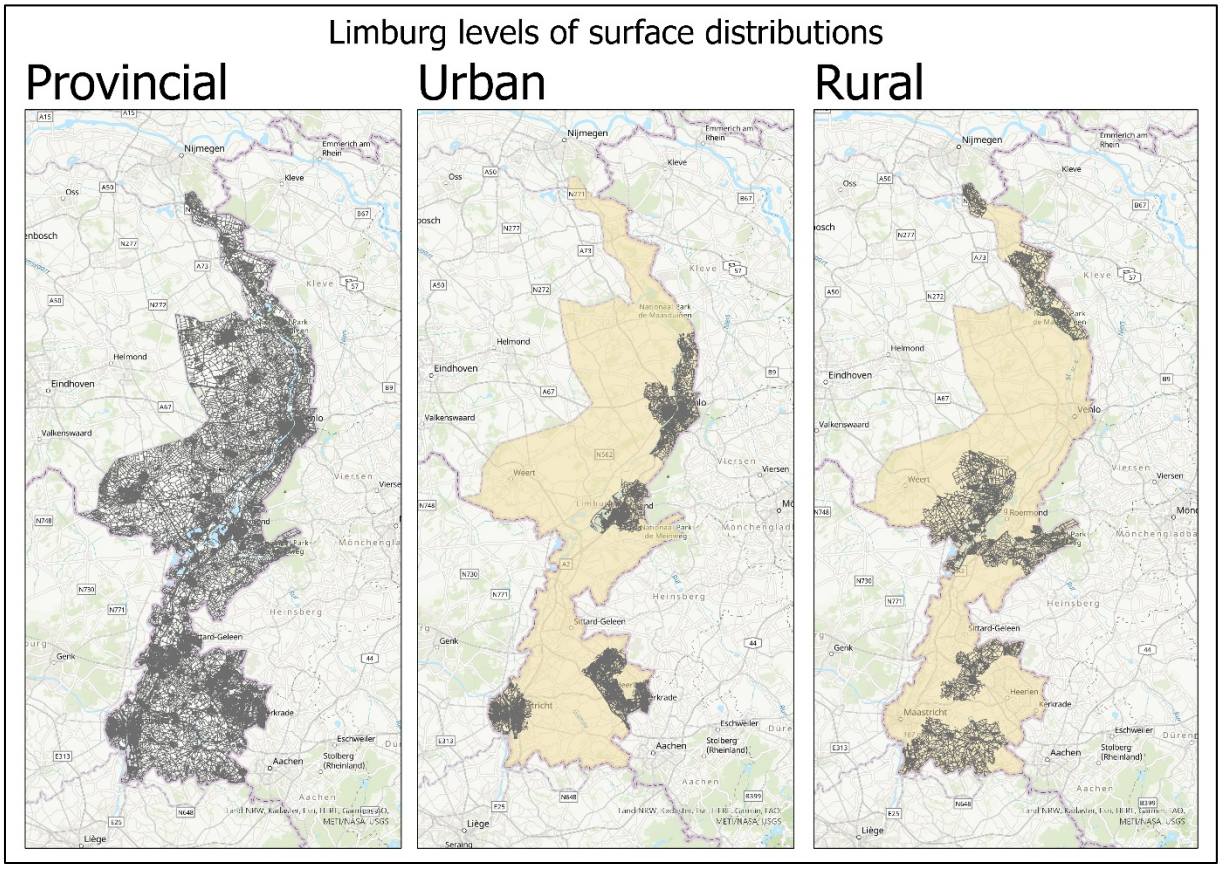


*Figure 3: GIS map of urban, rural and provincial surface analysis. (Source: Author)*

As visible in figure 4 there are no car roads visualized, however, still, the road network of Groningen is visible due to the infrastructural network of pedestrians and cyclists (which are often right beside car roads). The bicycle surface seems less dominant in this figure than the surface dedicated to walking while Groningen is regarded as a bicycle city. Yet, looking at the statistics gained from this analysis, bicycle lanes make up for 2.569.829,5 square meter while pedestrian surface occupies 8.218.622,1 square meter.

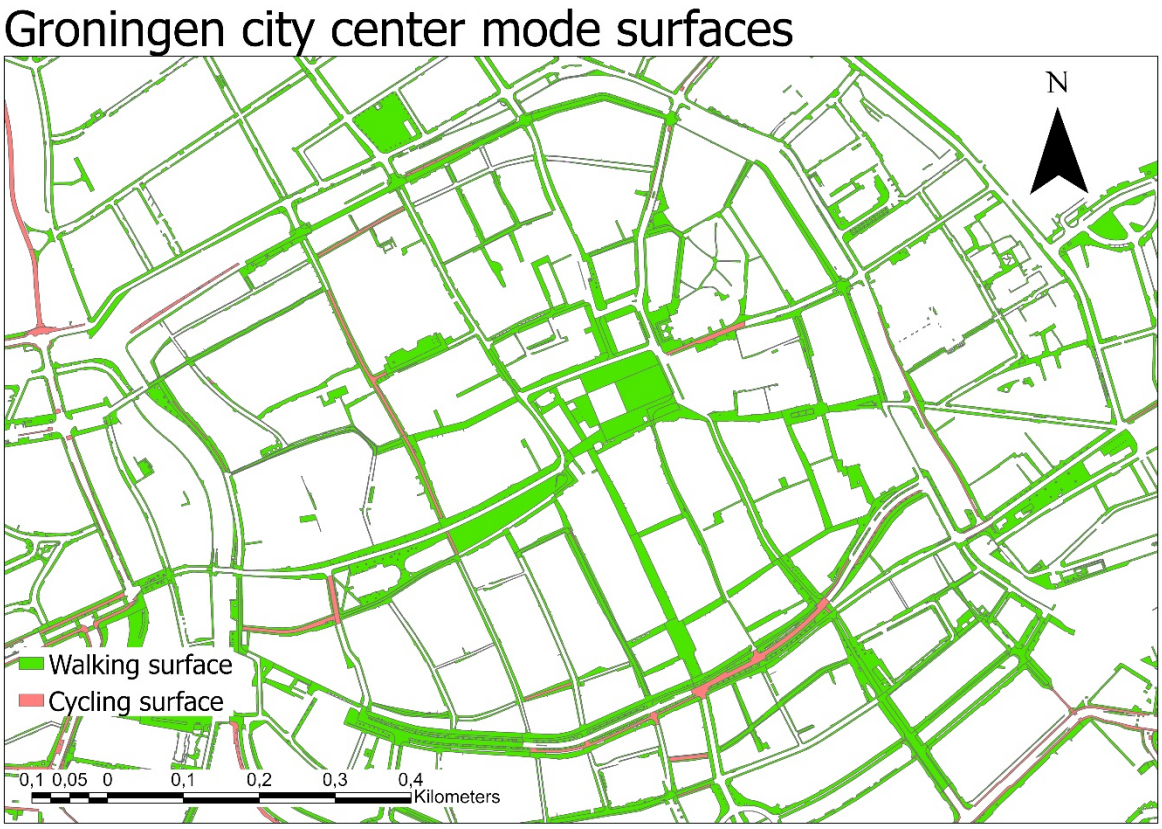


*Figure 4: GIS map, walking and cycling surface Groningen center. (Source: Author)*

### 6.2 Comparison within provinces

For this part of the result, analysis histograms are put in place per selected province. In the histograms, the total split of the surface distribution is depicted as well as the urban and rural split. The surface distributions of the provinces are visualized in histograms because the results are better comparable than in loose pie charts. The modal splits depicted in the pie charts (figure 8,9 and 10) are included in the histograms to be able to compare the surface distributions of the provinces to the modal splits as well. Parking spots are not a part of the modal split as they are not a mode of transportation. This is why there is no yellow bar in the category parking spots.

#### 6.2.1 Groningen

For the province of Groningen, the car use (depicted in the provincial modal split) is lower than the surface percentage dedicated to car use in the province as a whole as well as in the urban and rural areas in Groningen. In this province, a very little amount of the surface percentage is dedicated to public transport. However, the use of public transport (within the province) is a few percent nonetheless. This is partly due to the busses being able to drive on car roads and highways. Notable is that the bicycle use is higher in percentage than the surface percentages of the urban, rural and total area of the province.

The surface distribution of urban areas in Groningen is very different from the surface distribution of rural areas in Groningen.

- The surface percentage dedicated to cars is much higher in rural areas than in urban areas.
- Bicycle lanes occupy an almost similar percentage of surface in the urban regions and urban regions.

- Surface dedicated to walking paths is relatively more occurrent in urban areas than in the rural ones.

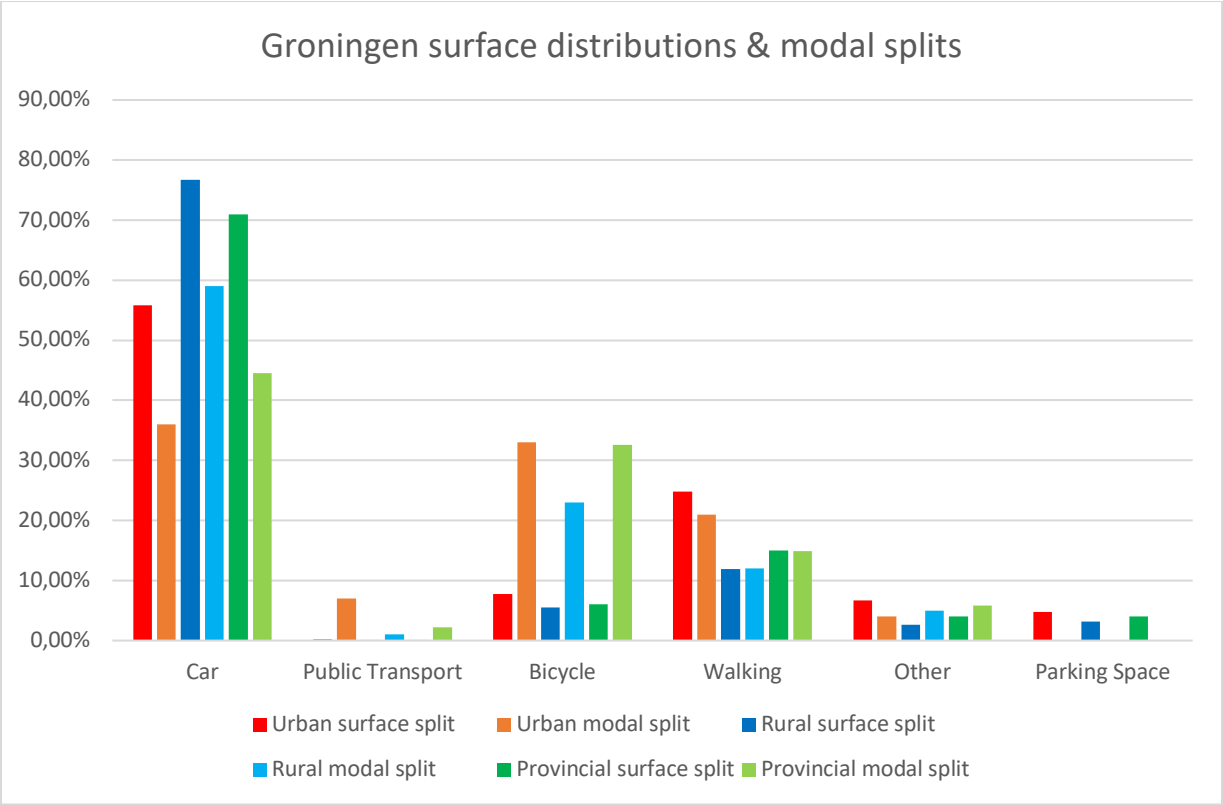


*Figure 5: Bar chart of statistics from the GIS analysis (Source: Author)*

### 6.2.2 Noord-Holland

In the province of Noord-Holland, the percentage of car use is almost similar to the percentage of the urban surface percentage of cars. On the contrary, the rural surface percentage of cars almost doubles the share that car use has in the modal split of the province of Noord-Holland.

As in Groningen, the bicycle use percentage is much higher than the percentage of surface dedicated to bicycle paths in urban and rural regions of Noord-Holland as well as the province as a whole.

Notable differences in urban and rural areas are:

- The percentage of car dedicated surface in rural areas almost doubles the percentage of car surface in urban areas
- The percentage of walking paths in urban areas is about 3 times as big as the percentage of walking paths in rural areas
- The share of rural cycling paths is bigger than the share of urban cycling paths in their respective surface split

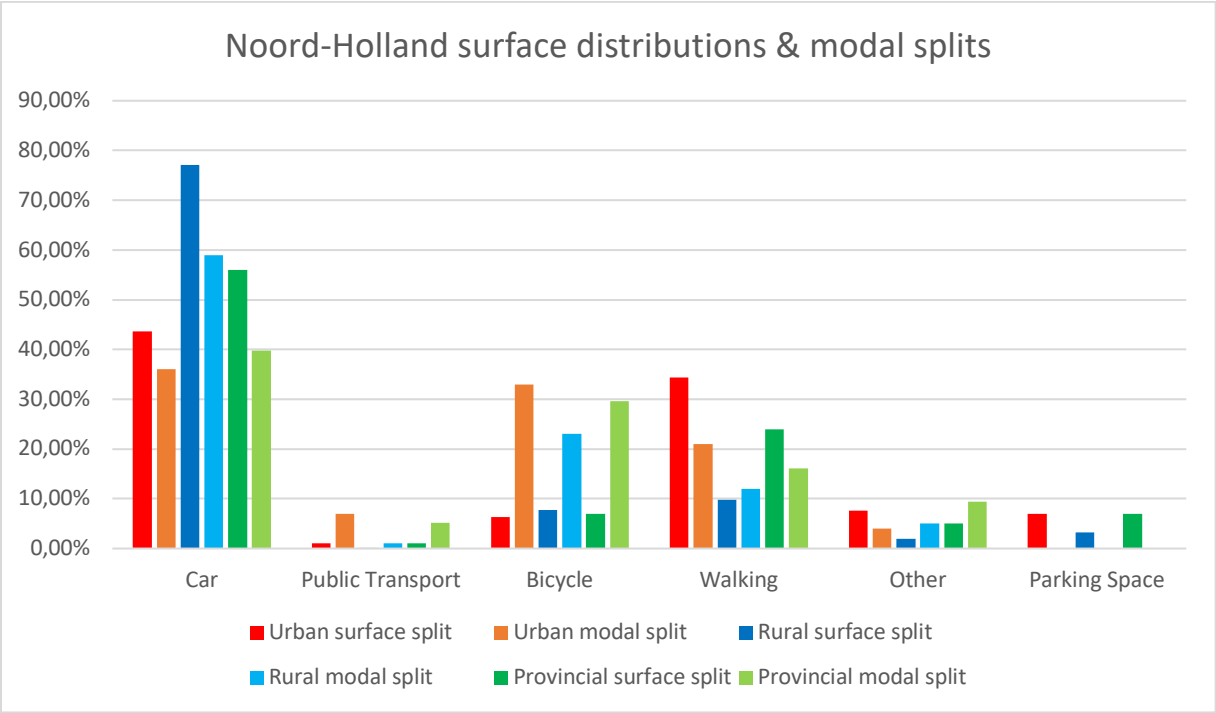


*Figure 6: Bar chart of statistics from the GIS analysis (Source: Author)*

### 6.2.3 Limburg

In Limburg, car use makes up for more than half of the provincial modal split and the reason for this could be that the surface share that is dedicated to car use is 67% in this province, that is about 2/3$^{rd}$ of all the street surface dedicated to transportation. Furthermore, the share of surface space dedicated to walking is almost similar to the share of pedestrians in the provincial modal split.

Notable differences in urban and rural areas are:

- Relatively small urban share of car committed street surface compared to the rural car surface.
- As in the other provinces, the urban street surface consists of walking space for a bigger part than in the rural area of Limburg.

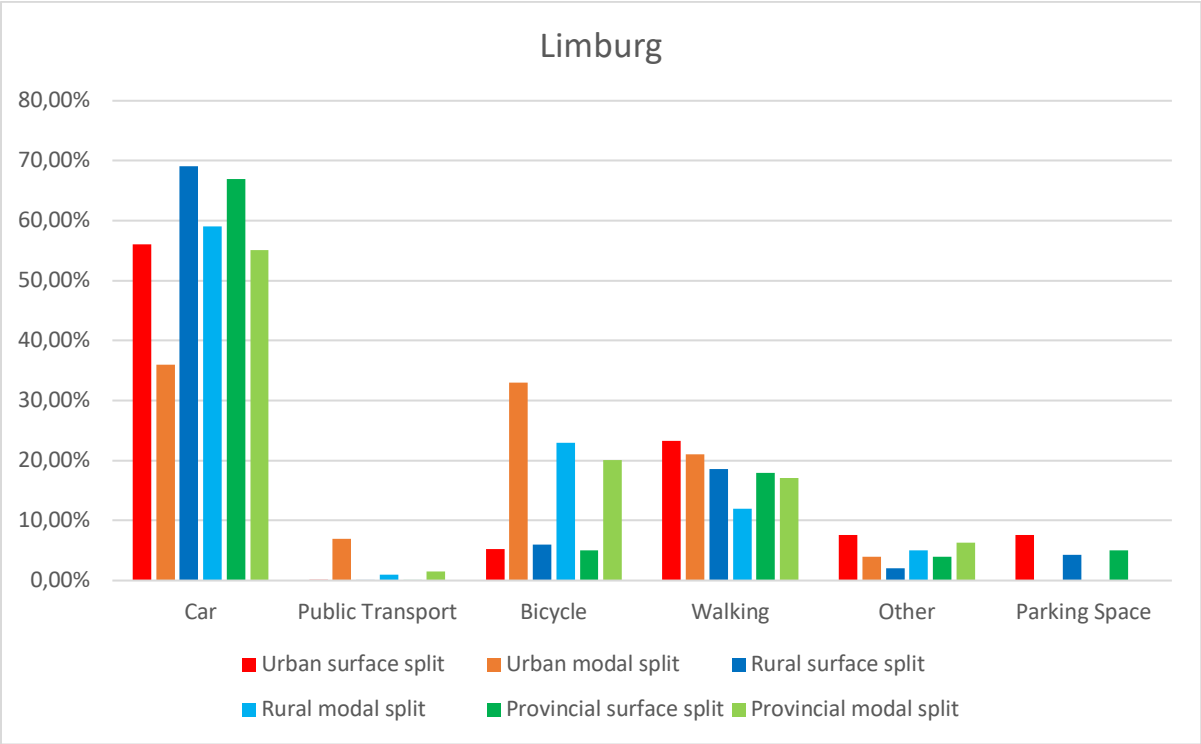


*Figure 7: Bar chart of statistics from the GIS analysis (Source: Author)*

### 6.3 Comparison between provinces

The following part of the data analysis will compare the provincial modal splits (further referred to as just modal split) (depicted in figure 8,9 and 10 and statistics in table 1) and the surface dedicated to the transportation modes of the selected provinces against each other. This will be done to see if there is a relationship between modal split and street space distributions that is occurring in different cases. To be able to refer to the statistics found on all the 3 provinces, a table has been made (table 1) with the modal splits of all 3 provinces as well as the street surface distributions (urban, rural and total).

*Table 1: statistics Dutch provinces (Source: Author based on CBS)*

| TABLE 1 | Groningen | Noord-Holland | Limburg |
|---|---|---|---|
| **Modal Split (province)** | | | |
| Car | 44,57% | 39,78% | 55,11% |
| Public transport | 2,17% | 5,11% | 1,46% |
| Bicycle | 32,61% | 29,65% | 20,07% |
| Walking | 14,86% | 16,06% | 17,15% |
| Other | 5,79% | 9,47% | 6,28% |
| Parking places | x | x | x |
| **Total Street Surface Distribution** | | | |
| Car | 71% | 56% | 67% |
| Public transport | 0,01% | 1% | 0,10% |
| Bicycle | 6% | 7% | 5% |
| Walking | 15% | 24% | 18% |
| Other | 4% | 5% | 4% |
| Parking places | 4% | 7% | 5% |
| **Urban Street Surface Distribution** | | | |
| Car | 55,85% | 43,66% | 56,11% |

| | | | |
|---|---|---|---|
| Public transport | 0,17% | 1,09% | 0,13% |
| Bicycle | 7,74% | 6,33% | 5,27% |
| Walking | 24,75% | 34,32% | 23,30% |
| Other | 6,70% | 7,58% | 7,63% |
| Parking places | 4,77% | 7,03% | 7,56% |
| **Rural Street Surface Distribution** | | | |
| Car | 76,76% | 77,15% | 69,04% |
| Public transport | 0,05% | 0,03% | 0,06% |
| Bicycle | 5,52% | 7,71% | 6,01% |
| Walking | 11,90% | 9,80% | 18,55% |
| Other | 2,60% | 1,93% | 2,01% |
| Parking places | 3,16% | 3,30% | 4,32% |

The first thing to note about the comparison between the 3 provinces is the relatively low share of car use in Noord-Holland compared to the other 2 provinces. With 39,78%, car use in Noord-Holland has the smallest share of car use amongst the 3 provinces. The street surface share in Noord-Holland is also lower than in the other 2 provinces. This mainly results from the proportionately low urban share of street surface committed to car roads.

When the share of car surface is (relatively) low in Noord-Holland a mode should be higher than in the other provinces to make up for that difference. This is in Noord-Holland the share of public transport in both the modal split and the surface split. As explained before the shares of public transport seem small in the modal split and surface split since only trips within the province are taken into account and the only surface purely dedicated to public transport (so no mixed uses). Because every mode of transportation is analyzed the same way as public transport it makes for a reliable research method. Public transport shares in Noord-Holland are relatively high compared to the other 2 provinces. Again, the modal split of Noord-Holland, as well as the surface split of Noord-Holland, have the biggest share of public transport. These research statistics are in line with the literature that mentions that a better balance in the availability of transportation modes leads to less of a need for private motorized transportation (Geyer and Quin, 2019). Noord-Holland has the highest share of public transport use in both the modal split and the surface split and moreover the lowest share of car use of the selected 3 provinces.

Other statistics from the GIS analysis that show the influence of the surface distribution on the modal split is the bicycle statistics. In Limburg, the bicycle share of the surface split is the lowest and in the modal split, this is visible by a difference from approximately 10% from the other 2 provinces. This statistic could be explained by looking at the urban street surface of Limburg. The urban street surface possesses the highest share of car surface together with the lowest share of bicycle surface. One of the articles referenced in the theoretical framework states that cyclists feel less safe in an environment with many cars which makes it less safe for cyclists (Freund, 2012).

In most researches land use is the broad term used for using the physical environment to reshape travel behavior. However, regarding these articles (Zhang, 2004, 2006; Geyer and Quin, 2019), their theories share the statement that increased accessibility to a wide variety of transportation modes decreases the demand for private motorized vehicles (which are dominant currently). The following citation explains this theory: “More pedestrian- and cyclist oriented urban design makes these modes more likely to be considered by the traveler” (Zhang, 2006). In combination with the results of this analysis this research assumes that in fact there is (to an unknown degree) an interrelation between the modal split and the street surface distribution of a place. However, an even balance between

accessibility of modes is the main strategy to make a transition away from the car as the dominant transportation mode.

### 6.4 Analysis modal splits

In figure 8,9 and 10, the modal splits of the 3 provinces that are analyzed for this research are depicted in pie charts.

It is visible that there is a relatively big difference amongst the modal splits of these 3 provinces as there is almost a 15% difference in car use between the provinces of Noord-Holland and Limburg. However, the ranking of the modes is similar in every province. Ranking from the car as the most used transportation mode, which is in line with the literature about the car system we live in (John Urry, 2004; Freund, 2012), to the bicycle as second-most (Jonkeren O. *et al.*, 2019), walking as third and public transport (train excluded) as last right after the other modes of transport categorized as collective.

Further notable observations in the modal splits are the very little shares of public transport, much lower than the national share (*CBS Statline*, 2018). This is mainly because of the statistics of the CBS provide statistics on the trips made within the provinces themselves. For instance, bus trips from province to province or even further are not included in these statistics. This statistic is taken into account in the GIS analysis. The surface dedicated to public transport that crosses the border of one of the selected provinces is clipped to make sure only the surface areas are analyzed that are useful for this research.

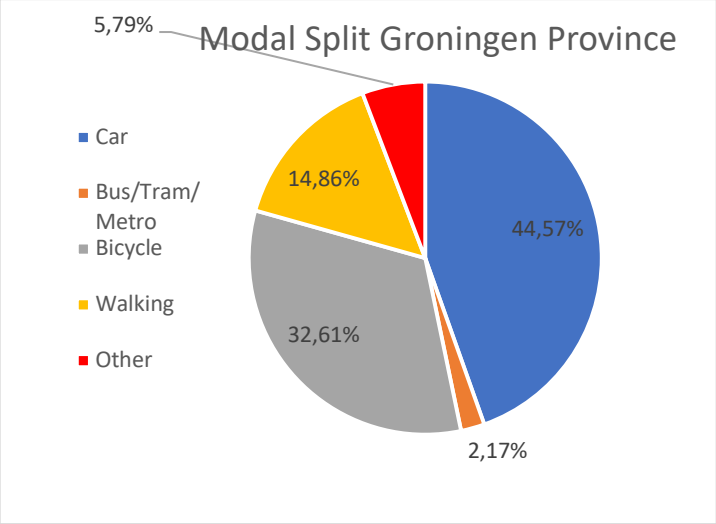


*Figure 9: Modal split Groningen province (Source: Author)*

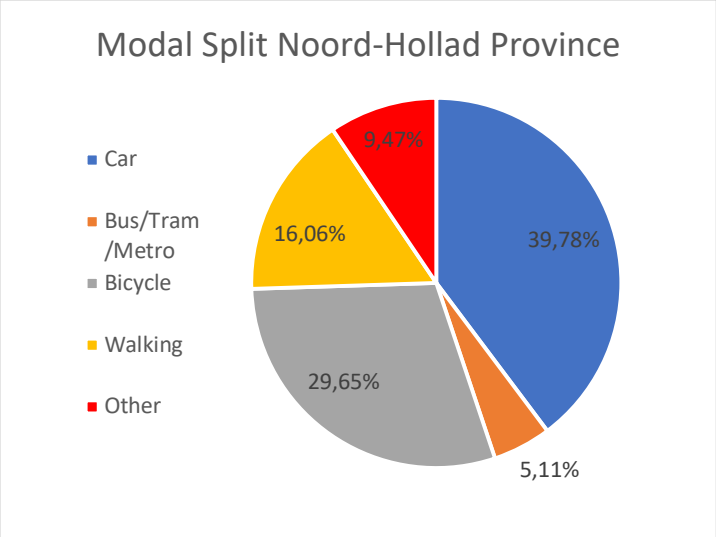


*Figure 8: Modal split Noord-Holland province (Source: Author)*

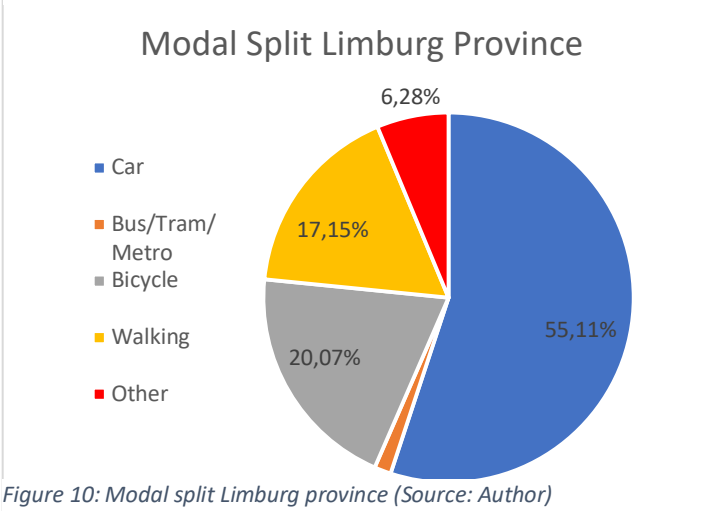


*Figure 10: Modal split Limburg province (Source: Author)*

## 7. Car Parking

The car as the main mode of transportation worldwide requires a lot of parking space, as cars are non-mobile most of the time. Space for car parking is mainly seen as a public amenity and people tend to presume that, to every place they travel, they will find places to park their car. This phenomenon leads to a less big of a boundary to take the car and thus to overall higher car use than in a case with controlled parking spots (Stephen G. Ison and Corinne Mulley, 2014). The ultimate goal of this part of the research is to contribute to the transition away from the automobile-system. Through analyzing the space occupied by parking space for cars and raising awareness on how much space is at stake and how it can be used otherwise this part of the research will try to complement to achieving that goal. In the provincial analysis of this study space for car parking is included in the street surface split for all three of the provinces. This is done to provide an insight for the readers of this research on the space (both urban and rural) that is occupied for the sole purpose of parking a car. The statistics found in table 1 tell us that car parking spots take up around 5% and in Noord-Holland even 7% of surface area that is dedicated to transportation in the selected provinces. To put this into perspective, in Groningen province provides 124.548.071,8 square meters of car roads and 7.003.080,6 square meters of parking space. Car roads only form 18 times the amount of space for a non-mobile car. So, the space for moving cars is only 18 times as much as space for non-moving cars. Considering this is only public parking and the parking space in residential areas such as driveways of houses is not taken into account in this analysis tells us how relatively big amounts of surface in Dutch provinces are occupied by parking space.

Multiple studies point out that this amount of space for car parking is excessive and not necessarily beneficial for the flow of traffic. A regular way of thinking is the more parking space, the faster people park their car. However, more parking space leads to more car use and can furthermore lead to vehicle circling in search of a parking spot closest to the destination of the car users' trip. This vehicle circling leads to extra traffic congestions and gas emissions which both have a negative influence on the urban environment (Geng and Cassandras, 2013; Mackowski, Bai and Ouyang, 2015).

### 7.1 Policies

In the Netherlands, some cities (for instance Groningen) try to ban cars as much as possible from their city centers at certain scheduled times. This is also effective for reducing car use and vehicle circling in the city center. However, several studies (Geng and Cassandras, 2013; Stephen G. Ison and Corinne Mulley, 2014; Mackowski, Bai and Ouyang, 2015) are proving that through smart systems and dynamic pricing, car parking could occupy much less space than it does nowadays while still enabling people to park their car when needed. The method that these articles suggest is a more sustainable way of coping with the problem of parking space than solely banning cars from city centers. When cars are banned from inner-city centers, they are not visible anymore but still need parking space in very close proximity to the city center. So, it is moving a problem from one place to another. In Figure 11 a layout view of the GIS analysis of Groningen is depicted with the parking spots in the city center selected (visible as dark brown color). This city banned cars from its city center and still has parking space available in almost every street. More sustainable measures against car use can be taken (in for instance Groningen city) through regulating parking space. This has proven to work according to the literature in this chapter of the data analysis.

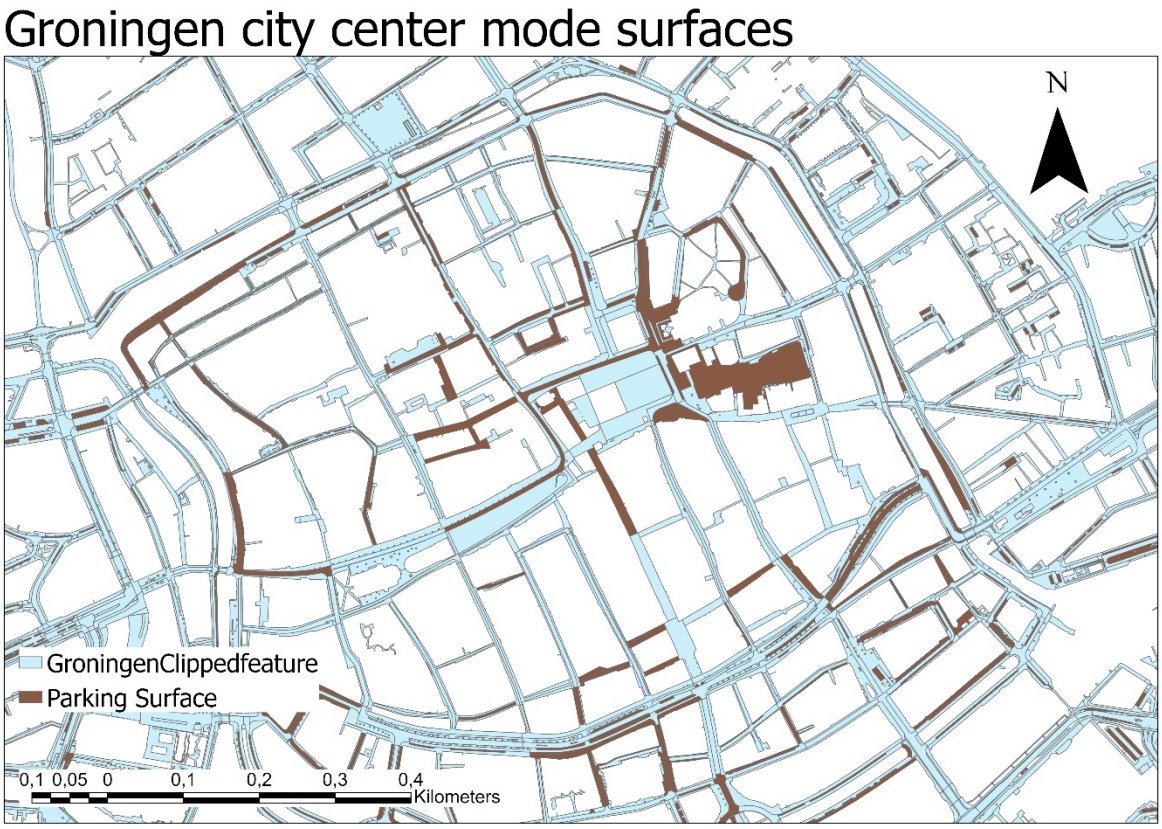


*Figure 101: Parking spots Groningen city center, indicated dark brown. (Source: Author)*

## 8. Conclusion

This research investigated the relationship of the modal split of Dutch provinces with the street surface dedicated to the modes used in those modal splits. Furthermore, the surface of parking space was looked into as this is a form of valuable (urban) surface which could be made use of in a more efficient manner. From the GIS analysis that has been carried out for this research, a statistical analysis was produced as the final result.

The main question of this research was: What is the influence of street space distribution on the choice of transportation mode in urban and rural areas of the Dutch provinces Groningen, Noord-Holland and Limburg? From the results of the GIS analysis, the assumption can be made that in fact there is an interrelation between modal split and street surface distribution. The modal splits of 3 provinces differed from each other in certain ways, such as Groningen and Limburg having a much higher car share in the modal split than Noord-Holland. Noord-Holland came out the cartographical analysis as the province with the lowest car share in the respective surface split, of all 3 provinces. This was the case for some more of the statistics that came out of the cartography analysis, but not for all of them. That not all of the results are explainable through the relationship of surface and the modal split has to do with the fact that there are a lot of factors influencing an individual in his/her mode choice (De Witte *et al.*, 2013). However, this research isolated the influence of street surface on the mode choice as good as possible. Frequently, the statistics of the modal split and the street space distributions show similarities when being compared to those of other provinces to assume

that there is a relationship between modal split and street surface distribution (Geyer and Quin, 2019).

Parking surface in the Dutch provinces analyzed in this research is not used to its maximal efficiency. Policies that are used are just mildly causing car use decline which is the goal when transitioning to other transportation modes. By integrating international examples of parking policies on the Dutch scale the Urban (and eventually rural) space dedicated to parking can be used for other purposes or in a more efficient way.

### 8.1 Reflection

A result that was found but not necessarily looked for in this research is the space efficiency of bicycles. Looking at the produced bar charts (figure 5, 6 and 7) the bicycle is the only mode where the actual percentage of use is always higher than the percentage of space dedicated to this type of transportation. This underlines the fact that the bicycle is one of the most sustainable modes of transportation (Pucher, Dill and Handy, 2010).

When the strength of the relationship between the surface distribution and the modal split is to be examined, the research must be carried out at a bigger scale than it was done in this study. Comparing 3 provinces can cause assumptions on a relationship but not provide certainty or factual proof of this relationship. Also, international examples could lead to very different outcomes, but they were not included in this research as the data on the street surface was very hard to come by. Therefore, suggestions for further research are: carrying out the same result on a larger scale, test the effect of alterations in surface splits on the modal splits of areas that are tested before, and test this factor against other factors such as supply and demand to see the size of this relationship. The goal of this research was complementing to the transition away from a car-centered society. By doing this research a door has opened to possibly advantageous future research for this transition. Furthermore, it raised the public awareness of sustainable travel, mode choice and the harm of excessive car use which contributes to this research goal.

**References**


Batterton, K. A. and Hale, K. N. (2017) 'The Likert Scale What It Is and How To Use It', *Phalanx*, 50(2), pp. 32–39.

*CBS Statline* (no date). Available at: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/84710ned/table?ts=1601034235737 (Accessed: 25 September 2020).

De Witte, A. *et al.* (2013) 'Linking modal choice to motility: A comprehensive review', *Transportation Research Part A: Policy and Practice*, 49, pp. 329–341. doi: 10.1016/j.tra.2013.01.009.

Delucchi, M. and Kurani, K. S. (2014) 'How to have sustainable transportation without making people drive less or give up suburban living', *Journal of Urban Planning and Development*, 140(4). doi: 10.1061/(ASCE)UP.1943-5444.0000172.

Dendrinos, D. S. (1976) 'Mode Choice, Transport Pricing, and Urban Form', *Environment and Planning A: Economy and Space*, 8(7), pp. 767–778. doi: 10.1068/a080767.

Freund, P. (2012) 'Automobility and Its Discontents', *Capitalism Nature Socialism*, 23(3), pp. 118–122. doi: 10.1080/10455752.2012.701870.

Geng, Y. and Cassandras, C. G. (2013) 'New "smart parking" system based on resource allocation and reservations', *IEEE Transactions on Intelligent Transportation Systems*, 14(3), pp. 1129–1139. doi: 10.1109/TITS.2013.2252428.

Geyer, H. and Quin, L. (2019) 'Social diversity and modal choice strategies in mixed land-use development in South Africa', *South African Geographical Journal*, 101(1), pp. 1–21. doi: 10.1080/03736245.2018.1522270.

John Urry (2004) 'The "System" of Automobility', *Theory, Culture & Society*, 21(4–5), pp. 25–39. doi: 10.1177/0263276404046059.

Jonkeren O. *et al.* (2019) 'The bicycle-train travellers in the Netherlands: personal profiles and travel choices', *Transportation*. doi: 10.1007/s11116-019-10061-3.

Mackowski, D., Bai, Y. and Ouyang, Y. (2015) 'Parking space management via dynamic performance-based pricing', *Transportation Research Part C: Emerging Technologies*, 59, pp. 66–91. doi: 10.1016/j.trc.2015.05.021.

Meyer, M. D. and ITE (Institute of Transportation Engineers) (2016) *Transportation Planning Handbook*. Somerset, UNITED STATES: John Wiley & Sons, Incorporated. Available at: http://ebookcentral.proquest.com/lib/rug/detail.action?docID=4591867 (Accessed: 25 September 2020).

'Mode choice for VFR journeys' (1998) *Journal of Transport Geography*, 6(1), pp. 43–51. doi: 10.1016/S0966-6923(97)00038-0.

Pucher, J., Dill, J. and Handy, S. (2010) 'Infrastructure, programs, and policies to increase bicycling: An international review', *Preventive Medicine*, 50(SUPPL.), pp. S106–S125. doi: 10.1016/j.ypmed.2009.07.028.

Rojas López, M. C. and Wong, Y. D. (2019) 'Process and determinants of mobility decisions - A holistic and dynamic travel behaviour framework', *Travel Behaviour and Society*, 17, pp. 120–129. doi: 10.1016/j.tbs.2019.08.003.

Stephen G. Ison and Corinne Mulley (2014) *Parking : Issues and Policies*. United Kingdom: Emerald Group Publishing Limited (Transport and Sustainability). Available at: http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=839244&site=ehost-live&scope=site (Accessed: 26 November 2020).

Vanoutrive, T. (2015) 'The Modal Split of Cities: A Workplace-Based Mixed Modelling Perspective', *Tijdschrift voor economische en sociale geografie*, 106(5), pp. 503–520. doi: 10.1111/tesg.12113.

Williams, D. G. (1971) 'The Modal Split: The Relevance of American Experience for Britain', *The Town Planning Review*, 42(2), pp. 181–194.

Zhang, M. (2004) 'The Role of Land Use in Travel Mode Choice: Evidence from Boston and Hong Kong', *Journal of the American Planning Association*, 70(3), pp. 344–360. doi: 10.1080/01944360408976383.

Zhang, M. (2006) 'Travel Choice with No Alternative: Can Land Use Reduce Automobile Dependence?', *Journal of Planning Education and Research*, 25(3), pp. 311–326. doi: 10.1177/0739456X05280544.

Zheng, N. and Geroliminis, N. (2013) 'On the distribution of urban road space for multimodal congested networks', *Transportation Research Part B: Methodological*, 57, pp. 326–341. doi: 10.1016/j.trb.2013.06.003.

**Appendix**

CBS stats: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/84710ned/table?ts=1601034235737

All statistics used are visible in the graphs that are used in this research paper.