Understanding the trip and user characteristics of the combined bicycle and transit mode

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ABSTRACT

Several cities around the world are facing mobility related problems such as traffic congestion and air pollution. Although limited individually, the combination of bicycle and transit offers speed and accessibility; by complementing each other's characteristics the bicycle and transit combination can compete with automobiles. Recognising this, several studies have investigated policies that encourage integration of these modes. However, empirical analysis of the actual users and trips of the combined mode is largely missing. This study addresses this gap by (i) reviewing empirical findings on related modes, (ii) deriving user and trip characteristics of the bicycle and transit mode in the Netherlands, and (iii) applying latent class cluster analysis to discover prototypical users based on their socio-demographic attributes. Most trips by this mode are found to be for relatively long commutes where transit is in the form of trains, and bicycle and walking are access and egress modes respectively. Furthermore, seven user groups are identified and their spatial and temporal travel behaviour is discussed. Transport authorities may use the empirical results in this study to further streamline integration of bicycle and transit for its largest users as well as to tailor policies to attract more travellers.

1. Introduction

Cities around the world face several (increasing) problems. Apart from traffic congestion, the significant portion of air pollution and consequent respiratory health issues are well known. Furthermore, over-reliance on cars has lowered liveability in cities by reducing the space available for human interaction and through fragmentation of the urban fabric (Federal Ministry for Economic Cooperation and Development, 2009).
Having identified these problems, authorities often seek to increase the modal share of active modes such as walking and cycling, and transit modes such as metros, bus rapid transit systems and trains (European Commission, 2011). These modes are more effective from a passenger perspective and contribute to efficient, sustainable and economically vital cities (Van Oort et al., 2017a). However, due to their individual limitations, these modes are unable

to compete with automobiles: active modes have a low spatial reach due to low speed and high effort whereas transit modes, by nature, do not provide door-to-door accessibility. The car, on the other hand, is a flexible mode capable of overcoming limitations of both these modes.

The combination of bicycle and transit has been identified as a powerful combination (Brand et al., 2017). Active modes and high-level transit, combined offers speed and accessibility in the range of personal vehicles or para-transit modes by complementing each other's characteristics (Figure 1).

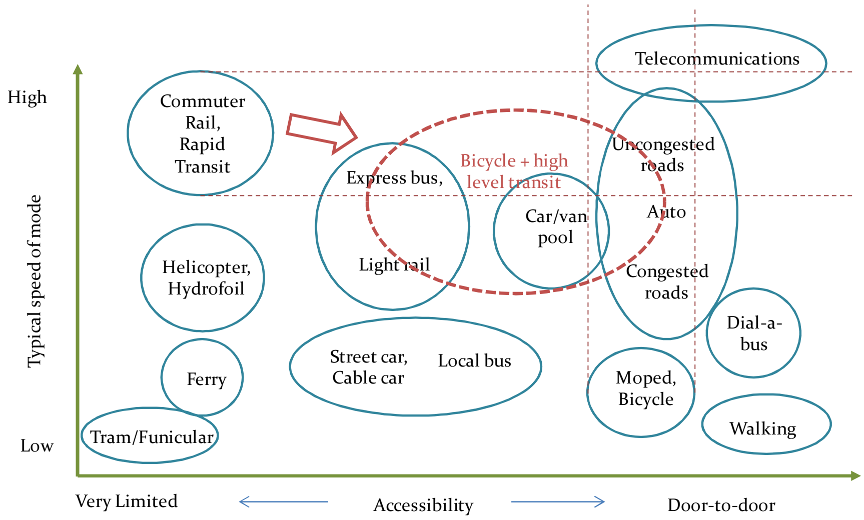

Figure 1: The position of the bicycle and transit mode amongst others according to speed and accessibility (modified, Kager et al., 2016)

On one hand transit is able to overcome the distance barrier that the bicycle alone faces; on the other, compared with walking, using bicycles as an access/egress mode significantly increases the catchment area of transit stations, and therefore potentially overcoming the first and last mile hurdle that high-level transit faces. This synergy between bicycles and transit has been noted by researchers, transportation institutes and policymakers for its potential to increase sustainability, efficiency and equity of transportation in cities around the world. Thus, it is not without reasons that active efforts are made towards integration of these two modes. (Krizek and Stonebraker, 2011).

Efforts are measures such as improved bicycle tracks to and from transit stations, parking facilities at stations, ability to carry bikes on transit modes and creating availability of public bicycles (Federal Ministry for Economic Cooperation and Development, 2009). In the Netherlands, such services are present almost ubiquitously for all high level transit modes and almost 47% (Kager et al., 2016) of the train passengers use a bicycle in some part of their trip chain. Moreover the Dutch Government recognises the potential of this combined mode and considers maximizing its share as a policy challenge (Rijksoverheid, 2016).

Although the synergy of bicycle and transit has been recognised and several efforts towards better integration of these modes have been made, a scientific understanding of the users and trips of this mode is lacking. The common, ultimate goal of all stakeholders here is to increase the share of the sustainable bicycle and transit mode by shifting travellers away from the use of private cars. In order to achieve this, it is important to understand the current use of the bicycle and transit mode to maintain and increase its share by encouraging likely users to divert to this mode. The factors affecting the use of this combined mode can be divided into four parts: *1)* policies, *2)* infrastructural facilities, *3)* user characteristics, and *4)* travel characteristics. While infrastructural facilities and policies regarding the integration of bicycle and transit have been discussed extensively, few studies consider the actual trips conducted or those who make the trips.

Understanding which trips and users the bicycle and transit mode is suitable for enables policy makers to make relevant decisions regarding the infrastructure and service investments to be made in order to increase its modal share. Such decisions could be regarding the type of service required, or to prioritize investments. Furthermore, it is likely that marketing strategies, to encourage modal shift, will also benefit from this study.

Therefore, this study is not only motivated by the gap in scientific literature regarding this topic but also by the existing need to support decision making, and more, in order to increase this combined mode’s share and thus enable more sustainable transportation.

This paper is organised as follows:

After this introduction, the existing literature will be shortly described to determine the contextual framework of this study. In the next chapter, a focus will be laid on the methodology of this study. From there on, a shift is made towards results in chapter 5. Chapter 6 describes the conclusions of this study. Finally, acknowledgements and references will be the last part of this paper. First of all, to avoid misunderstanding the next part will describe definitions used in this paper.

Definitions

Defining the mode using the entire trip allows decision makers to consider all segments of the trip to increase the combined use of bicycle and transit. Using this system level definition, complementary modes such as walking and feeder transit can also be accordingly planned. For the purposes of analysis, this paper uses the definition of the bicycle and transit mode of Kager et al. (2016), which are displayed in Figure 2:

A trip is said to make use of the bicycle and transit mode if the trip has, as its main mode, a transit trip, in the form of a train, bus, tram or metro, and makes use of sustainable modes: walking, cycling or feeder transit, to access and egress it such that at least one of the access and egress trips is a bicycle trip.

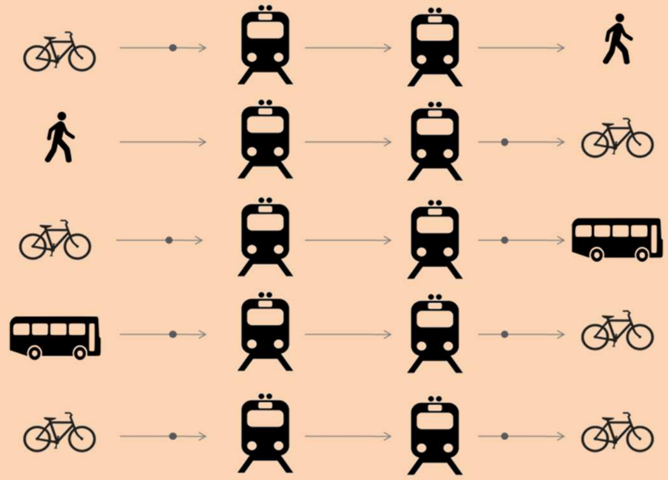

Figure 2: Bicycle and transit trip types: 1) Cycle - transit - walk; 2) Walk - transit - cycle; 3) Cycle - transit – feeder transit; 4) Feeder transit – transit – cycle; 5) Cycle – transit - cycle

Different nomenclatures for different parts of a journey from an origin to a destination have been found in literature and therefore, in order to avoid confusion; the terms used in this paper are defined here. Four parts are differentiated: *1) trip segments* – travel using a single mode continuously; *2) trip part* – position of travel in the whole journey from origin to destination: access, main or egress; *3) trip* – travel from an origin to a destination; *4) trip chain* – a series of consecutive trips starting and ending at home. Thus, trip segments make a trip part, trip parts constitute a single trip and a series of trips makes up a trip chain.

2. Literature Review

The potential of bicycle and transit as a combined mode has been recognised in literature, with most of the work on this topic occurring in the previous two decades (see for instance Flamm and Rivasplata, 2014; Hensher and Reyes, 2000; Pucher and Buehler, 2009; Rietveld, 2000; Tsenkova and Mahalek, 2014; Van Oort et al. 2017b). Western European countries like Netherlands, Denmark, Germany and the United Kingdom; and North American countries such as the United States of America (USA) and Canada are well represented in literature whereas there is little or no research from South America, Africa and Asia. In this literature review the main focus will be on research considering the integration of cycling and transit.

The combined bicycle and transit mode is, by its nature, an example of multimodality within a single trip. A single trip can be composed of several segments which can be divided into three parts: access, main, and egress parts. The main part is defined as that segment of the trip that is the longest in distance whilst the other parts are either for access or egress (Krygsman and Dijst, 2001). In their paper, Kager et al. (2016) propose defining bicycle and transit as a combined mode when main transit is accessed and egressed by only walking, cycling or feeder transit, and a cycling segment is directly connected to at least one end of the main transit segment. They attribute the ability of the mode to compete with cars to the ‘synergy’ between the high speeds of transit and door-to-door accessibility of bicycles. Further, the combined mode increases the catchment area of transit while increasing cycling and reducing the need for feeder transit (Krizek and Stonebraker, 2010).

Although very few works analyse the use of bicycle and transit mode directly, several studies have been conducted to understand the modality patterns of travellers and the conditions associated with them. The variables affecting the choice of bicycle and transit mode are a combination of those affecting cycling, transit and multimodality. In their literature review of commuting by bicycle, Heinen et al. (2010) classify determinants into the built environment; natural environment; socio-economic attributes; psychological factors; and aspects related to cost, effort and safety. In addition to this, the social environment and culture regarding cycling is an important factor in its use (Handy et al., 2014). Transit is essentially multimodal in nature as it lacks the door-to-door connectivity of the bicycle or the car. Multimodal transportation depends strongly on trip characteristics such as access/egress distance to main mode (Krygsman et al., 2004), activity purpose, duration and sequence (Susilo and Dijst, 2009); car ownership and household interactions deciding car availability; socio-demographic characteristics (Krygsman and Dijst, 2001; Nobis, 2007); and activity location and spatial characteristics (Krygsman and Dijst, 2001).

Such studies use a variety of data sources like trip diaries, panel mobility surveys or surveys designed specifically for the concerned experiment. Trip diaries provide information on socio-demographic characteristics and trips by individuals or households for a specified period ranging usually from one to seven days (CBS and RWS, 2011-2016). The large number of respondents makes it possible to derive characteristics of users of different modality patterns. Longitudinal or panel surveys usually have a lower number of respondents but record a person or household's trip for a longer duration than just one day over several years. They enable researchers to correlate modality with life changes or built environment changes (Hoogendoorn-Lanser et al., 2015). Finally, self-designed surveys are typically to extract attitudinal characteristics or opinions (Heinen and Bohte, 2014), or to focus on a particular mode (Bachand-Marleau et al., 2011) and are used because national mobility surveys typically lack such information or because the data available cannot be used with the desired analysis.

The most common form of analysis is to relate the variables described previously to assumed segments of travellers and to use tests of relationship to find statistically significant trends. This generally forms the basis of most quantitative analysis and helps to create an interesting image and interpretation of survey data (e.g. (Kennisinstituut voor Mobiliteitsbeleid, 2015; Martens, 2014). However, researchers are often interested in predicting the modality category of a traveller using different variables; to this end regression methods such as binary or multinomial logistic regression are used (e.g. Nobis, 2007; Buehler and Hamre, 2015). Basically, classification techniques, such as logistic regression, use a set of responses or records to train a model, by adjusting coefficient values associated with different variables, to predict the category membership of an observation on the basis of its variables. A binary logistic regression model helps to know whether a particular observation belongs to a category or not while a multinomial logistic regression model classifies an observation into one of several categories. The interpretation of the coefficients of a logistic regression model can help in characterising the users of a modality pattern.

Although this is quite useful already, Anable (2005) states that in mode choice research, traveller segmentation is usually based on priori socio-demographic characteristics, resulting in possibly heterogeneous groups, unlike studies in customer behaviour and marketing where the aim is to target homogenous groups. She argues that market research has shown that treatments, such as transportation policies, receive the best response when applied to homogenous groups and therefore traveller segmentation should be based on more complex set of characteristics. Cluster analysis, an exploratory statistical technique, can achieve this aim by forming groups of observations that are different from each other but similar within themselves. These groups can then be interpreted to translate into target groups that emerge from an objective analysis of the data such that pre-conceived notions play a minimal role. If several variables in the data set are expected or found to be correlated (for example, certain trip purposes may be correlated with certain modes (Olafsson et al., 2016) then factor analysis is used to condense them into fewer measures so that these correlated measures do not have an inordinate effect on the clustering. After this the regression scores of each observation are used as input to a clustering algorithm such as K-means (Anable, 2005; Bachand-Marleau et al., 2011; Olafsson et al., 2016). However, clustering techniques have drawbacks regarding the type of data they can handle, the fact that they deterministically assign observations to groups and that the number of clusters to be used is not always very clear. Another technique, latent class cluster analysis, claims to be able to overcome these drawbacks (Magidson and Vermunt, 2002) and therefore Molin et al. (2016) choose to use this technique to identify modality patterns of travellers and their characteristics. Latent class analysis first identifies clusters on the basis of selected indicators (the measurement model) and then identifies the probability of different people being in a cluster according to their personal characteristics (the membership model) (Molin et al., 2016).

Only a handful of studies directly studying the trip attributes of bicycle and transit mode have been found. Martens (2004) compares the Netherlands, Denmark, Germany and the United Kingdom on the share of bike and ride and collects values for the Netherlands on a number of relations. As expected, Netherlands and Denmark, which have high shares of cycling, have the highest share of transit users with bicycle as an access mode. In the Netherlands, whilst the share of bicycle as access mode is 32.7%, as an egress mode its share is only 8.8% (Krygsman and Dijst, 2001, processed); as stated previously this is due to the asymmetry of bicycle availability. Further, the combined mode is used mostly for daily activities (such as work and education) rather than incidental activities such as shopping (Martens, 2004). Concurrently, the use of *OV-fiets* (cycle renting scheme) as egress mode is for more infrequent activities where people may not have a second bicycle (Martens, 2007).

Access and egress are critical segments in transit trips as their importance in terms of effort or perceived time spent is much higher than their contribution in reaching the destination. The catchment area of a transit stop depends (to varying degrees) on trip characteristics such as access/egress mode, transit mode or service and trip purpose.
Intuitively, the catchment area using walking to access/egress will be smaller than cycling because of the lower speeds and greater effort in walking. Krygsman et al. (2004) find, using observed travel times, that the median access distance by cycling is 1.8 km while by walking is 550 m and the median egress distances are 2.4 km and 600 m respectively. Further, they find that the travel time decay for both modes is nearly the same in access and slightly slower for bicycles in egress indicating that travellers seem to have a travel time budget for access and egress. However, from stated preferences of those willing to combine cycling and transit, Bachand-Marleau et al. (2011) conclude that higher access/egress times on a bicycle are more acceptable than by walking. Based on a mobility survey in the Netherlands,

(Keijer and Rietveld, 2000) calculate the share of different modes for different distance classes and find that walking dominates access trips up to 1.5 km and egress trips up to 2.5 km . The switch to bicycles at 1.5 km at the home-end, and the fact that at the activity end feeder transit is used more commonly for distances too great to walk indicate the effect of bicycle availability on mode choice. Based on the fact that most access and egress trips are up to 2.5 km, walking and cycling are the most common access and egress modes. Brand et al. (2017) demonstrated that access and egress distances to stops of high quality transit lines are about twice as large as those of regular transit.

Although the above mentioned references provide many insights, empirical analysis of the actual users and trips of the combined mode is largely missing. Our research focuses on this gap. The next section will present our approach.

3. Trip and User Characteristics

To analyse the trip and user characteristics, data derived from a national data survey has been used. In the first section the data set has been described. The second and third section focus on the way the data has been used in the descriptive analyses and the latent cluster analysis respectively.

3.1 Data set Description

To gain insights into the current characteristics of bicycle and transit users we used a Dutch one-day trip diary survey, Mobility Survey in the Netherlands (in Dutch: *Onderzoek Verplaatsingen in Nederland*, OViN (CBS and RWS, 2011-2016). Individuals are asked for their personal and household characteristics as well as details regarding all the trips they make on a particular day. The target population of the OViN is the entire Dutch population and it has a large sample size with over 250,000 persons interviewed in six years from 2010 to and including 2015; representative for the entire Dutch population. Table 1 partitions the main variables used or considered in the analysis into these categories.

Table 1: Variables in the OViN dataset used in the analysis

Socio-demographic	Travel related
Household	**Overall**
• Number of persons in the household • Household composition • Degree of urbanization of residence • Disposable household income • 4 digit postcode of home address	• Reporting date and day of week • Total travel duration in the day • Total distance travelled in the day
Individual	**Trip**

• Gender • Age • Nationality • Mode of social participation • Highest education	• Trip has the same origin and destination • Number of trip segments • Trip destination • Trip motive • Departure and arrival postcodes • Trip distance • Main mode used in trip • Departure and arrival times • Trip travel time • Activity duration
Transportation	**Trip segment**
• Number of cars in the household • Driving license • Main user of a car in household • Transit use frequency • Student smart card availability	• Trip segment distance • Trip segment mode • Trip segment departure and arrival times • Trip segment travel time

The reliability of the representativeness of the OViN data quickly deteriorates as the more conditions are applied to filter the dataset, or if it is sought to analyse rare situations. However this situation is likely to improve as more data is added over the years.

3.2 Combined bicycle and transit mode in the dataset

It is assumed that the mode used for the access and egress trip part, respectively, is the mode that is used for the longest distance amongst other trip segments. This definition is reasonable in most cases as people are unlikely to have very complex trip compositions due to the cost of transferring and the fact that if a particular mode can be used for a significant portion it is likely to be used for the entire trip part. When no access or egress mode is stated, to or from transit modes, a separate trip part is not perceived and this can be described as a ‘Very Short Walk’. To identify the main trip part, this study uses the main mode stated in the OViN dataset. in the series of trip segments, any trip segments between those carried out by the stated main mode are enchained trip segments; those before the first main mode trip segment are access trip segments; and those after the last main mode trip segment are egress trip segments

In order to define trip chains, our research defines five types of trip bases or starting points: 1) home, 2) work, 3) education, 4) other activity and 5) unknown. The starting location affects the choice of modes that the traveller can use. The first recorded trip of a traveller has ‘home’ as its base unless the motive target is ‘travelling to home’ in which case the trip base is ‘unknown’. This happens because the nature of the survey - a one-day trip diary – may result in incomplete travel records

Each record in the dataset represents one trip segment so that multiple records make up a trip, then a trip chain and finally all the travel carried out by the respondent. Table 2 provides a data summary of the OviN database.

Table 2: Number of records in each derived data file

Data file	Level of aggregation/Filter	Number of records	%age relative to overall
OViN	Trip segments/None	806,011	-
Trips	Trips/None	684,245	*Overall*
Socio-demographic (*Users*)	Respondent persons/None	252,110	*Overall*
Multimodal trips	Trips/Trip segments > 1	35,466	5.2%
Multimodal trip chains[1]	Trips/Trip segments > 1	20,433	6.8%
Multimodal users[2]	Trips/Trip segments > 1	19620	7.8%
Bicycle + transit trips	Trips/See mode definition	5943	0.9%
Bicycle + transit trips chains	Trips/See mode definition	3401	1.1%
Bicycle + transit users	Respondent persons/Mode users	3376	1.3%

3.3 Clustering Bicycle and Transit Users

In addition to obtaining the bicycle and transit trips and users and to discuss their aggregate characteristics, the next step in our research is to move on to a more disaggregated level in order to identify the types of bicycle and transit users and their trip making characteristics.

Cluster analysis is a type of unsupervised learning that uses unlabelled data to classify multivariate data into natural groups such that the observations within a cluster are highly similar to each other but are very dissimilar to observations in other clusters (Han et al., 2006; Izenman, 2008). Since the objective in this chapter is to identify prototypical users or, to put it differently, classify bicycle and transit users into natural groups, cluster analysis is very useful. Clustering is used in a wide range of studies but here the objective is similar to that of marketers who use this technique to segment markets into small homogeneous groups so that campaigns can be carried out efficiently (Izenman, 2008). In this study the dataset has a mixture of data types; for example trip purpose is categorical while age is continuous. Latent class cluster analysis (LCCA) is able to handle such data and has some other advantages as well which led to its choice for this study

LCCA has certain advantages that make it more attractive to use for the given study (Vermunt and Magidson, 2002):

- In cluster analysis one of the common problems is deciding the adequate number of clusters. LCCA provides local and global measures to make this decision on the basis of formal statistical criteria.

[1] Trips chains consisting of at least one trip that is of the mentioned type (multimodal or bicycle and transit respectively)

[2] Travellers making at least one trip of the mentioned type (multimodal or bicycle and transit respectively)

- Because of the underlying statistical model, it is also possible to check the significance of the model parameters.
- LCCA can take as input categorical and numerical variables as it is not based on proximity measures but on a statistical model.
- Variables also do not have to be scaled to prevent larger value variables from dominating the process unlike other algorithms.

This study uses LatentGOLD 5.1 which is a commercial software from Statistical Innovations for applying LCCA. The following are the steps that were used in applying LCCA:

1. For each variable the data type must be set to either ordinal, nominal, continuous or count. If required case weights can be applied.
2. Identify the number of clusters required. The different criteria that can be used are given in Table 3
3. Understand the properties of the clusters in the final model. Based on this, the clusters can be identified or given a name based on the general outlook of the properties.
4. Identify cluster membership of each observation by exporting from LatentGOLD to SPSS for further analysis of the clusters.

The objective of applying a LCCA here is to find prototypical users of the combined bicycle and transit mode. The observations input are only bicycle and transit users and therefore the indicator variables all consist of socio-demographic characteristics while there are no covariates. The indicator variables used can be classified into three types as shown in Table 3. For a detailed overview of the used LCCA-methodology in respect to the OViN-database, see Shelat (2016), including the re-categorization of variables as well as the cluster modelling.

Table 3: LCCA indicator variables

Category	Indicator variables
Household	• Household composition • Home location • Household income (standardized 10th percentiles)
Individual	• Gender • Age group • Education • Social participation mode
Transport	• Car availability • PT use frequency

4. Results

This section presents our main findings with regard to the Trip and User Characteristics and Clustering Bicycle and Transit Users. The first section is split into three parts, the first part shortly deals with findings for main travel modes. The following two parts deal with the access/egress modes and the bicycle and transit mode respectively. The second section of this chapter describes the user characteristics in further detail.

4.1 Trip and User Characteristics

4.1.1 Main Modes

In general, it is seen that bicycles are the most preferred mode for users within smaller distances: from approximately 1 to 1.5 kilometres. At the opposite, trains are largely used to travel distances larger than 10 kilometres. Less clear, however, is the distance travelled by other transit (3-40 kilometres), this also makes sense since the category of bus, tram, metro is quite diverse within itself.

Besides distances, travel time is an important indicator of connectivity. The decay curves of walking and cycling are nearly similar. However, due to the higher speed, cyclist can cover a larger distance within the same acceptable time. Further on, it can be seen that the same counts when walking and cycling are used as access and egress modes for transit, thus indicating a larger catchment area for cyclists in comparison with walkers.

In terms of socio-economic variables, car and train are more used by higher income users. This is likely since the daily urban system of higher income users is larger than the one of their lower income counterparts. Since higher incomes travel more by train, and have a wish to travel further, they are more likely to be bicycle and train users. Bus, tram and metro, at the other hand are more used by lower income classes.

4.1.2 Access/Egress Modes

Transit users are more willing to travel larger distances towards train station than towards bus, tram and metro stations: 3.8 versus 1.5 kilometre respectively. The same applies for egress distances but with smaller distances travelled, namely 2.7 versus 0.7 kilometres respectively. These mentioned distances counts for travellers of transit in general, thus also with either access or egress modes different than a bicycle. Based on these numbers, it can be seen that travellers are either reluctant to combine cycling with bus/tram/metro or do not have the facilities to do so.

In comparison with main modes, the access distance is larger when the distance travelled by main mode is larger too. Although this is true for both train and bus, tram, metro travels, the increase rate is higher for bus, tram and metro than train. A positive relation is also found between the frequency of transit use and the use of the bicycle as an access mode. This is mainly due to the fact that the bicycle and transit mode is often used for work, business and education purposes which are likely to be activities done more than once a week.

4.1.3 Bicycle and Transit Mode

As earlier mentioned, the bicycle and transit mode is multimodal by its nature. This multimodal characteristic already implies that the distance travelled by bicycle and transit is longer than average. The average distance travelled by bicycle and transit is about 41 kilometres. The distance is likely to be larger when transit also has a feeder function, however, this is not the most common trip combination. Often the bicycle is used as an access mode, followed by transit and walking as an egress mode.

82.8% of the transit within these trips is ‘train’, whereas the remaining 17.2% consist of bus, tram or metro as the main mode. The majority of trips is used to go to work or education, starting home (or going home in the opposite direction). The trip objectives already imply that most trips are made multiple times per week (89% of the users) and mostly on weekdays during morning rush hours.

The people making the bicycle and transit trips are equally represented by males and females. This equality, however, does not count of the level of education: higher educated people use the bicycle and transit mode more than lower educated people. This is understandable since it is already proven that the bicycle and transit mode is an ideal mode to travel longer distances and higher educated, working people are more likely to travel further to work than their lower educated counterparts.

4.2 Clustering Bicycle and Transit Users

The OViN-data set is used to determine the bicycle and transit users by defining clusters with a Latent Cluster Analysis. Seven mutually exclusive groups have been defined. Based on the properties of the clusters, each cluster is given a title defining the prototypical user represented by that cluster. It should be noted that this label is a subjective, average group definition and does not imply that all bicycle and transit users belonging to a cluster have the properties of the label. Regarding the reliability of the results all clusters have >100 observed users except for ‘Pensioners’ who have 80 members, which is also the smallest group within the total pool of bicycle and transit users. The group sizes are displayed in Figure 3. The next sections describe the groups separately.

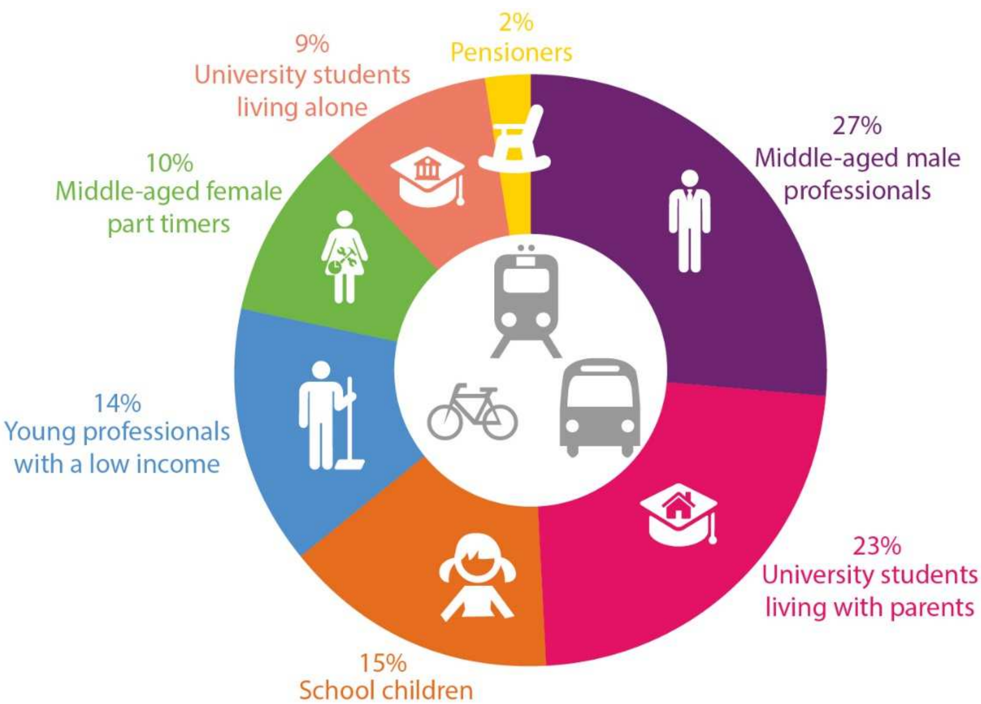

Figure 3: Seven identified clusters of bicycle and transit users as a result from the LCCA.

The smallest cluster, **pensioners**, is by far the smallest group. Pensioners represent just over 2.4% of the total group of bicycle and transit users. This size is actually too small to gain reliable results of this group, the group has, however, been added since their properties are too different from the other groups. Furthermore, adding this group makes it possible to have a mutually exclusive set of user groups. Most of the members are highly educated and approximately 40% of these travellers always have access to a car. Further reinforcing the idea that this group is not very important for the bicycle and transit mode is the fact that they are not regular transit users and most of them use transit either once-a-week or once-a-month.

In terms of group size, the pensioners are followed by **university students living alone** (9.5%). A large portion, 20%, uses this mode to visit someone. Of further interest is the fact that, like the part-timers of the next group, the share of those using transit daily is less than half. This means that a large share of travellers do not use the bicycle and transit mode daily. Like the young, low income professionals (cluster 4) nearly 90% of this group's members never have access to a car and are therefore captive users of the bicycle and transit mode.

The third group, **middle-aged female part-timers** represent more or less the same size (9.7%) as the aforementioned group. This group is very similar to the first group of middle-aged, male professionals in terms of income, household composition and age. However, 90% of the members of this group are female and three quarters of the members do not always have access to a car. And, as the title of this cluster suggests a majority of the members are part-time professionals.

The remaining four groups are all larger than 10% of the total group of bicycle and transit users. 14% of the users are **young professionals with a low income**. This is one of the groups comprising of full-time workers but it has several differences with the final, and largest one. The members of this group are younger, earn lesser and have an almost equal distribution of gender. Moreover almost nobody in this cluster has children although nearly a quarter lives with a partner. About 80% of these travellers never have access to a car, making them captive users of this combined mode.

The group size of **school children** is 1,1 percentage point larger than the young professionals, giving it a 15.1% size. Hence the name of the group, school children, these group consists of young people, equally divided by gender, have no access to cars and as expected, living with their parents. Although it is likely that these children do not contribute to the household income, the household income of this group tends to be on the lower side. The average main mode distance is 25 km, lower than the average by a little more than 10 km and subsequently, nearly 40% of the trips made by this cluster use bus/tram/metro as the main mode, more than double of the average of bicycle and transit trips. 70% of the trips use walking as the egress mode while almost 20% of users cycle to their final destination.

By far the largest groups are **university students living with parents** (22.8%) and middle aged, male professionals (26.5%). To start with the penultimate one, university students living at parents, are equally represented by men and women and come from all strata of household income groups. Further, as one would expect, most of them have no or limited access to the household car and are therefore daily transit users. About a quarter of these travellers use bus/tram/metro as their main mode – higher than the combined mode average – and significantly less (10% points less) people use the bicycle at the egress end, instead replacing it with feeder transit and walking. The mean distances for the three trip parts do not differ much from the average of all clusters.

The largest group, finally, are **middle aged, male professionals**. More than a quarter of the bicycle and transit mode users belong to this group. Most of the members of this group are middle-aged (35-64 years) working men, highly educated and from high income households. Nearly all of them live with a partner while almost half have kids. They are generally (90%) one of the core members of the household and nearly half the times, the household's main car user. This means that even though a car is available to these travellers they choose to use the bicycle and transit mode. Most of the members of this group live in urban and suburban regions of the country and travel to extremely or strongly urbanised areas with the purpose work.

5. Conclusions

The bicycle and transit mode is attracting attention from research and policy-makers alike from around the world as a sustainable mode that is able to compete with the car. Although there is a growing interest in this mode and its benefits, not all its dimensions have been studied very well. Several research articles, guides and manuals exist on the policies and methods suitable for the integration of the bicycle and transit but literature addressing its usage characteristics is still quite rare. From the different factors affecting the use of the bicycle and transit mode the trip and user characteristics are quite important. Knowing which types of travel and for whom the bicycle and transit mode is suitable is likely to be very helpful in designing policies and services that encourage the use of this mode. With this motivation, this study analysed the user and trip attributes of the bicycle and transit mode in the Netherlands.

This study presents research on combined bicycle and transit mode, consisting of (i) reviewing empirical findings on related modes, (ii) deriving user and trip characteristics of the bicycle and transit mode in the Netherlands, and (iii) applying latent class cluster analysis to discover prototypical users based on their socio-demographic attributes. Most trips by this mode are found to be for relatively long commutes where transit is in the form of trains, and bicycle and walking are access and egress modes respectively. Furthermore, seven user groups are identified and their spatial and temporal travel behaviour is discussed. More than a quarter of the bicycle and transit mode users belong to the group of Middle-aged, male professionals. Most of the members of this group are middle-aged (35-64 years) working men, highly educated and from high income households. Nearly all of them live with a partner while almost half have

Transport authorities may use the empirical results in this study to further streamline integration of bicycle and transit for its largest users as well as to tailor policies to attract more travellers. The next step in bicycle and transit research should be analysing and understanding the attitude and preferences of the current and future users to enable predictions of combined transit and bicycle ridership. Trade-offs should be analysed to find the expected (societal) costs and benefits of changes in either bicycle and/or transit design and planning.

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