Development of cycling and influential demand factors in the Netherlands

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Abstract: In the Netherlands, the share of the bicycle as the main mode in all person trips has been highly constant in the past three decades (about 27%). A constant share is remarkable because developments in this period were mainly unfavourable for bicycle use, like ageing of the population, growing number of immigrants, increasing car ownership, and a tendency to travel larger distances. The analysis of the paper confirms that, if only the autonomous developments on the demand side of the modal choice market are considered, a large majority of these is adverse for bicycle use. Estimations with a model show that, indeed, a decreasing trend in the market share of the bicycle could be expected, while a stable trend is observed. Probably, supply-side developments, in particular the long-term bicycle-friendly policy of the Dutch national and local governments, had a significant positive influence on bicycle use.

Keywords: bicycle, the Netherlands, modal choice, long-term development

1. Introduction

In the Netherlands, the market share of the bicycle as the main mode in all person trips has been highly constant in the past three decades (about 27%). This constant share followed a large decrease in the 1950s and 1960s, and a partial recovering in the 1970s. A constant market share during a longer period is in itself not surprising. However, it becomes remarkable if one considers that a number of developments in the past decades were unfavourable for bicycle use, like ageing of the population, growing number of immigrants, increasing car ownership, and a tendency to travel larger distances. Van Boggelen and Jansen (2007) expect a decrease of bicycle trips by 3% in a 20-years period in the Netherlands due to ageing, and an additional decrease of 2% due to a growing number of immigrants. Why do we still not observe a decreasing market share for the bicycle? Are there other, less conspicuous developments on the demand side that are conducive to cycling? Or do the developments on the supply side, like extended bicycle infrastructure and improved vehicles, compensate for the negative impact of the autonomous developments? The paper focuses on the question whether the demand-side developments are really negative for cycling and can or cannot explain the constant market share. In the case of "cannot", supply-side developments are likely to play a role.

One should note that the study area, the Netherlands, is rather exceptional in an international context because of the high bicycle use (Pucher and Buehler, 2008). The bicycle is not a "fringe mode" that "represents rare behaviors" (Krizek and Johnson, 2006), like in the US where a lot of bicycle research is done. In the Netherlands, the bicycle is used regularly by a majority of the population. In further contrast to many other countries, nearly all bicycle trips are made for transportation. Only 3-4% are not derived (just go for a ride). In the US, the latter cover more than two-thirds of the bicycle trips (Handy et al., 2010). Dutch research can give a useful contribution to the existing knowledge because usage of the bicycle is common practice. Likewise, Dutch findings may not always be valid in other, low cycling countries.

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The analyses of this paper are limited to adults. The latter are defined as persons aged 18 or older. From the age of 18, people in the Netherlands are permitted to get a driver's license. A further limitation is that only the choice for the bicycle as the main mode for trips is considered. The spectacular growth of the bicycle as an access mode to the train, resulting in large storage problems at the Dutch railway stations, is no subject of this paper. The main mode of a (multimodal) trip is defined as the mode that is used for the longest leg of the trip. The analysis starts with an investigation which variables affect significantly the choice to use the bike for a trip (Section 2). The examined variables are mainly variables on the demand side of the modal choice market, describing the autonomous determined environment for the choices. Then, in Section 3 an overview is presented of the developments of the significant variables in the past three decades. This answers the question to which extent the autonomous developments have really been adverse for cycling. To get an idea of the balanced impact of the analysed variables, the market shares of the bicycle in the past decades will be calculated using the model coefficients that are estimated on recent data; this is a kind of backcasting. The estimated market shares will be compared with the observed ones. The outcomes are briefly discussed in Section 4.

2. Factors associated with cycling

A number of studies have been carried out on explanatory factors for cycling. Regarding demand variables, that are subject of this paper, Handy et al. (2010), and Krizek and Johnson (2006) found a negative influence of age and a positive influence of education. Krizek and Johnson found additionally a relatively high bicycle use by men, a low bicycle use by employed persons, and a negative correlation with income. Handy et al. observed a positive relation with environmental concern and a strong negative correlation with trip distance. In the Netherlands, Rietveld and Daniel (2004), and Ververs and Ziegelaar (2006) uncovered a correlation with political colour –people are less (more) inclined to use the bicycle in right-(left-)wing municipalities–, and negative influences of urbanisation and relief. Ververs and Ziegelaar found in addition an association with religious denomination; Moslems are less inclined to use the bicycle than Christians, and within the Christian groups Protestants have a higher bicycle use than Roman-Catholics. They also observe a relation with weather. Another Dutch study demonstrates a large difference between immigrants and natives (Harms, 2006); natives use the bicycle more frequently.

Some of the studies demonstrate that supply factors play a significant role as well, both supply of infrastructure and facilities for the bicycle, and supply for alternative modes. Handy et al. found that a network of separated bike paths encourages cycling, Rietveld and Daniel found a positive relation with satisfaction level with the municipal bicycle policies and negative relations with the frequencies that cyclists have to stop or experience hindrances on the route. They observe positive relations with the bicycle speed compared with the car speed, and with parking costs for the car. Pucher and Buehler (2008) state that safety for cyclists is perhaps the most important variable that explains why bicycle use is high in some countries and low in other. Safety is closely related with the existence of dedicated infrastructure for cyclists. The impacts of supply factors imply that a demand-based analysis will not correctly describe the actual development if supply factors changed significantly.

2.1. Data and variables

We did an additional analysis of factors associated with cycling, using recent data from the Dutch National Travel Survey. Respondents of this survey are asked to report characteristics of the trips that they made in a predefined period (usually a day), and characteristics of themselves and their households. The survey is conducted continuously since 1978 and has been subjected to some significant changes in the survey design, influencing the registered

travel behaviour. The data include most of the autonomous demand variables but give no information about the supply side. The samples are always large, at least ten thousands of respondents annually. We explored the two most recent available databases, the OViN-data from 2010 and 2011.

The influences of next variables are investigated:

Characteristics of the household:

- Income (6 classes, ranging from $< \pounds 10,000$ to $>= \pounds 50,000$ per year).
- Household size (5 classes).
- Car ownership. We tested two measures for this factor: the number of cars (4 classes), and the cover ratio of the cars. The latter is calculated as the number of cars divided by the number of adults (aged ≥ 18) and has a maximum value of 1.0.
- Urbanisation of the home municipality, defined on basis of the density of addresses in the living neighbourhood (6 classes).
- Predominant denomination of the province. Three classes are defined: the protestant provinces in the lowly urbanised parts of the country, the highly urbanised western provinces ("Randstad") that are mainly protestant as well but house in addition a large number of Moslems, and the Roman Catholic provinces.

Characteristics of the traveller:

- Age (5 classes, ranging from 18-25 to >= 75 years old).
- Gender.
- Activity status (6 classes).
- Education (5 classes).
- Migrant's status (3 classes: natives, Western immigrants, non-Western immigrants).
- Bicycle ownership.
- Driver's license.
- Students pass for public transport.

Characteristics of the trip:

- Distance (22 classes of mostly 1 km width, the highest class ≥ 20.5 km).
- Season; this stands for the weather conditions and is defined cold in December to February, warm in May to September, and moderate in the remaining months.

Characteristics of the leg are not considered, because the analysis focuses on the use of the bicycle as the trip main mode.

2.2. Modelling bicycle choice

The influence of the variables on bicycle use is estimated by specifying and estimating a model that describes the choice to use the bicycle or not for a certain trip as a function of the explanatory variables. The estimation is performed in two steps. In the first step, the variables that are significant on a 95% level are identified. We used for this the Structural Equations Modelling (SEM) package AMOS 20. The SEM-technique can cope with interrelationships between exogenous variables that affect, and generally lower, the level of significance. In the second step, we estimated a binary logistic regression model where we included only the variables that proved to be significant in the first step. We used for this SPSS 19. Logistic regression seems the most appropriate technique for this kind of analysis, and it produces besides model coefficients a ranking of the variables. In both steps variables with more than two classes were split up into dichotomous variables. Next we will indicate dichotomous variables as 'classes' or 'categories' and use the word 'variable' for the original full variables.

In step 1, two variables proved to be not significant: gender and students pass for public transport. The absence of an influence of gender differs from findings in other studies. E.g., in the US a relatively high bicycle use by men is found (Krizek and Johnson, 2006). The

Netherlands seem to be rather exceptional regarding the impact of gender. Van Goeverden and de Boer (2013) found no impact of gender on modal choice by Dutch pupils as well, in contrast with Flemish pupils and with findings in other countries. Apart from non-significant variables, sometimes classes of a categorical variable did not differ significantly from the reference class.

In the model that is specified for step 2, we did not include the two non-significant variables, and we joined classes of a number of other variables: income (from 6 to 4 classes), activity status (from 6 to 4), education (from 5 to 2), migrants status (from 3 to 2), and distance (from 22 to 17). We selected the two measures for car ownership, because both proved to be significant, though to a different degree. The car cover ratio is much more significant than the number of cars in the household.

In step 2, using another technique, all selected variables were identified as significant again. Table 1 shows the contribution to the χ^2 value. The variables are ranked according to the inclusion in the model in the stepwise estimation procedure. Due to lack of space, the model coefficients are not shown here. The nature of the influences will be discussed in the next section.

	Increase χ^2
Trip distance	22346
Car cover ratio	4283
Bicycle ownership	6287
Season	1166
Activity status	256
Education	240
Driver's license	191
Type of province	208
Age	199
Number of cars	203
Urbanisation	131
Migrant's status	106
Household size	113
Income	63

Table 1 : Contribution to the χ^2

Many variables prove to influence bicycle use significantly, but they do so to a quite different extent. Most important is trip distance, other highly influencing variables are car and bicycle ownership, and travel season. The influences of the remaining personal and household characteristics are relatively small and rather close to each other.

3. Development of influencing factors

This section gives an overview of the developments of the significant variables since 1980 in the Netherlands in order to see whether the developments are favourable for cycling or not. It starts with controlling whether the same variables were significant in these decades and their influences did not change significantly. Then the developments of the separate variables are discussed.

3.1. Development of the influences

Using the same two-step procedure as described in Section 2.2, models were estimated on data from 1980-1981, 1995-1996, and 2008-2009. The rationale for the latter period, that is

close to 2010-2011, is a significant change in the set-up of the survey between 2009 and 2010, that might influence the results. The outcome is that the results in all periods are similar to a large extent. Distance is always most influencing, second and third are car cover ratio and bicycle ownership (in varying order). The influence of gender is never significant. Still, there are some notable differences:

- The students pass for public transport had a significant influence in 1995-1996 and 2008-2009, though it was the least important variable in both periods. In 1980-1981 the pass did not exist.
- Income was not significant in the other periods.
- Education was not significant in 1980-1981. Its influence was increasing in the three later periods.
- The influence of driver's license was decreasing between 1980 and 2008. This may have to do with the fact that it gradually became common practice to get a license by young adults.
- The difference between age classes, where the elderly (>= 75 years old) always are significantly less inclined to choose the bicycle than persons in the other age classes, became considerably less pronounced between 2008-2009 and 2010-2011. We assume that this has to do with the currently growing number of electric bicycles that facilitates cycling by elderly.
- The influence of the urbanisation of the home municipality shifted from negative to positive. In the first part of the period bicycle use was relatively high in lowly urbanised municipalities, while at the end of the period those living in highly urbanised municipalities had a relatively high inclination to use the bike. Still, bicycle use continued to be rather low in the largest cities.

Data about the migrant's status were not provided before 2010. We hypothesise that the influence will have decreased somewhat, assuming that a number of immigrants gradually assimilate and start to use the bicycle more frequently like the natives.

3.2. Development of the variables

This section pictures the developments of most of the variables mentioned in Table 1 and discusses to which extent the developments are favourable or unfavourable for cycling. Two variables from Table 1 are excluded: season and income. The first has no clear development, the second was hardly significant in 2010-2011 and not significant in any other period. The influence of a number of other variables is relatively small, but their aggregate impact can be substantial if the influences are in the same direction. The displayed developments are taken from the data of the NTS databases and regard only persons \geq 18 years old. The developments of household characteristics are shown on person level.

3.2.1. Trip distance

Bicycle use is moderate at distances < 1 km, highest at distances from 1 to 3 km, and slowly decreasing with further increasing distance. It is difficult to indicate typical cycling distances, but frequently 7.5 km is taken as the upper limit for a convenient cycling distance (e.g. by Rietveld and Daniel, 2004). Figure 1 shows that the share of cycling distances decreased a little. This observation is independent from the exact upper limit for a good cycling distance. The distance trends are unfavourable for cycling.

Figure 1 : Trends of distance classes



3.2.2. Car cover ratio

The car cover ratio is the number of cars divided by the number of adults and has a maximum value of 1.0. This variable is strongly negatively correlated with bicycle use. Figure 2 shows that the ratio increased significantly, so decreasing the potential of the bicycle.



Figure 2 : Trend of the car cover ratio

3.2.3. Bicycle ownership

Bicycle ownership increased in the 1980's and early 1990's, and remained stable afterwards (Figure 3). This observation is remarkable. In the Netherlands the notion is that everyone has a bicycle except for those who cannot use it for health reasons (mainly elderly) or never learned to bicycle and are hesitant to do so (mainly immigrants). Because the proportions of both elderly and immigrants are increasing (see Figure 8 and Figure 11), a decrease of bicycle ownership could be expected. The increase in bicycle ownership in the period before 1995 suggests that bicycle ownership is or was not fully determined by the ability and cultural habit to bicycle. This means that the development of bicycle ownership is not fully autonomous.

The autonomous part is likely to be adverse for cycling, the non-autonomous part encourages cycling, or did so at least in the period before 1995. Because the choice to buy a bicycle is closely related to the intention to use this mode, increased bicycle ownership cannot be considered as an explanatory factor for the stability of bicycle use in an adverse world as far as the ownership is not determined by health or cultural factors.

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Figure 3 : Trend of bicycle ownership



3.2.4. Activity status

Results of the model estimation demonstrate that bicycle use is lowest for persons that work full-time and highest for students. It is moderate for part-time workers and relatively low for the remaining categories. Figure 4 shows striking developments for three categories: the proportions of part-time workers and retired persons increased, and the proportion of those whose main activity is doing the housekeeping decreased. The development regarding parttime workers has no significant impact on bicycle use, the impacts of the two other developments balance out. Therefore, changes in activity status seem to have been rather neutral for bicycle use.





3.2.5. Education

Figure 5 : Trends of education classes



Education had no impact on bicycle use in the beginning of the considered period but became influencing to an increasing extent during the period. Highly educated people (academic) became significantly more inclined to choose the bicycle than the other people. Does education contribute to acknowledgement of health and/or sustainability issues of transport? Figure 5 shows that the proportion of academic trained persons increased considerably. This development is clearly favourable for bicycle use.

3.2.6. Driver's license

Ownership of a driver's license correlates negatively with bicycle use. The continuous growth of persons that get a license (Figure 6) is unfavourable for cycling.



Figure 6 : Trends of driver's license ownership

3.2.7. Type of province

Bicycle use is highest in the provinces that have mainly a protestant denomination outside the urbanised Randstad area. Second are the provinces that cover the Randstad; their denomination is mainly protestant as well, but there is also a large number of Moslems. In the typical Roman Catholic provinces bicycle use is lowest. Figure 7 shows that there has been no change in the proportions of people living in the different types of provinces. Therefore, this variable has no impact on trends in bicycle use.





3.2.8. Age

The main impact of age on bicycle use is a significantly lower use by elderly >= 75 years old. However this impact is recently decreasing. The growing number of elderly is unfavourable for bicycle use, though the decrease of the impact, suggesting an increased bicycle use by elderly, might have an opposite effect. For the whole period, the trends of age classes are likely to have been negative for cycling.



Figure 8 : Trends of age classes

3.2.9. Number of cars

The number of cars in the household is strongly negatively correlated with bicycle use. The strong increase in car ownership was unfavourable for cycling.



Figure 9 : Trend of car ownership

3.2.10. Urbanisation home municipality

The Dutch National Statistical Bureau classified urbanisation into five categories, ranging from not urbanised to very highly urbanised. We added a sixth category by dividing the 'very highly urbanised' category into two classes: the three largest cities (Amsterdam, Rotterdam and The Hague) and the remaining municipalities. Bicycle use is highest in these remaining very highly urbanised municipalities (density of addresses $\geq 2500/\text{km}^2$). Remarkably, bicycle use is relatively low in the two 'surrounding' categories: the three largest cities and the highly urbanised municipalities (density of addresses $1500-2500/\text{km}^2$). It is low as well in the not urbanised municipalities. Figure 10 shows that the main developments are a relative increase of persons living in highly urbanised municipalities and a decrease of those living in not urbanised municipalities. Both categories have a low bicycle use, and the two opposite developments have a balanced impact. However, the observations that on the one hand the urbanisation is generally increasing (Figure 10) and on the other hand the bicycle strengthened its position in urban areas, suggest that the impact of urbanisation has been slightly positive for bicycle use.

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Figure 10 : Trend of urbanisation of the home municipality

3.2.11. Migrant's status

Non-western immigrants are significantly less inclined to use the bicycle than natives. The model outcomes suggest a lower bicycle use by Western immigrants as well, but the difference does not meet the significance requirement. Figure 11 displays the developments. In contrast to the other graphs, it is not based on data of the NTS but on figures published by the Dutch Central Bureau of Statistics. That is because the older NTS databases (before 2010) give no information about the migrant's status of the respondents. The clear growth of non-Western immigrants is again an adverse development for cycling.





3.2.12. Household size

Figure 12 : Trend of household size



Bicycle use of singles is moderate. It is lowest for persons belonging to 2-person households, and increases when the number of household members increases, exceeding that of singles when there are 4 or more members. The clear reduction of the household size shown by Figure 12 is unfavourable for cycling.

3.3. Balanced development

The impacts of the trends of the individual variables on the choice for the bicycle are summarised in Table 2.

	Impact of trend
	on cycling
Trip distance	-
Car cover ratio	-
Bicycle ownership	?
Activity status	0
Education	+
Driver's license	-
Type of province	0
Age	-
Number of cars	-
Urbanisation	0/+
Migrant's status	-
Household size	-

The suspicion that the autonomous trends are adverse for cycling, expressed in the introduction, is confirmed for a majority of the individual trends. There is just one variable with a clear positive impact (education), and another variable that might have a positive impact as well (urbanisation). The increased bicycle ownership in the first part of the considered period was also conducive to cycling, but this is a difficult variable. In line with the question about the stable market share of the bicycle, one could wonder why more people decided to buy a bicycle when the autonomous developments are adverse for cycling.

The balanced impact of all variables can be displayed by 'backcasting' the market shares of the bicycle in the preceding decades using the model that is estimated on recent data, and comparing the estimated values with the observed ones. The outcome is pictured in Figure 13.



Figure 13 : Observed and estimated bicycle market shares

The estimated values in the figure are based on a model that is estimated on data from 2008 and 2009 unlike those from 2010-2011, because the former are more comparable to the older data due to a significant change in the survey set-up between 2009 and 2010. The figure includes the positive impact of bicycle ownership and excludes the negative impact of migrant's status because information on the latter variable is missing.

Figure 13 demonstrates that there is a clear gap between the estimated and observed developments. The balanced developments are indeed adverse for cycling and the question why the market share of the bicycle is constant over time is a legitimate one.

4. Discussion

In the paper we stated that a stable market share of the bicycle is unexpected considering the autonomous developments on the demand side. The question is why this happened. Probably, developments on the supply side counteracted the demand developments. Pucher and Buehler (2008) state that the Dutch bicycle system improved significantly since the 1970's. As reported in Section 2, some studies demonstrate that improved cycling conditions affect usage of the bicycle positively. However, the car system improved as well, and a negative impact of car quality on cycling is reported by Rietveld and Daniel (2004). Exceptions of the improved car system are a number of inner cities which access by car was restricted. In another paper, we explain that the increased problems to travel by car to inner cities are likely to account for a part of the gap between the estimated and observed national market shares of the bicycle (van Goeverden et al., 2013). Still, a part of the gap remains. This suggests that the efforts of the Dutch national and local governments to improve the bicycle system were effective in encouraging bicycle use. Assuming that many first world countries are faced with similar adverse autonomous developments, the resulting negative trend in bicycle use might be neutralised or even reversed by, among others, ambitious policies that promote cycling.

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