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Spatial and social variations in cycling patterns in a mature cycling country exploring differences and trends



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ABSTRACT

Despite the Netherlands' position as a premier cycling country (mainly due to its high cycling mode share), there is scarce insight into the variations of bicycle use between different spatial and social contexts as well as changes and trends over time. This gap severely limits the understanding of the context-specific aspects of cycling trends and hinders the development of effective policies to promote cycling. In order to fill this gap, this paper explores the spatial and social differentiation of cycling patterns and trends in the Netherlands.

First, an overview of the known spatial and social drivers of mobility behaviour in general, and of cycling behaviour in particular, is provided. Next, these insights are used to structure the analysis of data from the Dutch National Travel Survey (NTS). Mobility diaries allowed us to distinguish trends in mobility behaviour across different spatial contexts and social groups.

Our findings revealed three important spatial and social differences in cycling patterns and trends. First, the spatial redistribution of the population towards urban areas ('re-urbanisation') has led to increasing aggregated cycling volumes in urban areas, and falling rates in rural areas. Second, the general mode share of cycling is mainly sensitive to changes in the composition of the population, especially elderly persons (higher rates) and immigrants (lower rates). Third, although per capita changes are minor, cycling shares among young adults living in urban areas and elderly baby boomers are growing.

The results emphasize the need for a differentiated approach to promoting cycling and developing policies that can respond to location- and group-specific threats and opportunities. An awareness of these spatial- and social differences is especially important when cycling is used as policy intervention for public health; some groups and places are likely to profit, while others might remain immune. Additional research is needed to further clarify the drivers behind the observed trends and to fine-tune the intervention strategies.

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1. Introduction

Bicycle use in Western countries has been increasing in recent years. Cycling is not only becoming more popular in traditional biking countries like the Netherlands, Denmark and Germany (Pucher and Buehler, 2008, 2012), but also in countries where it is still marginal, such as the USA and Canada (Pucher et al., 2011). At the same time car use seems to be stagnating or even declining in North America and many West-European countries, which recently has generated a lively discussion in the literature on what is being called 'peak car' (Goodwin and Van Dender, 2013). Policymakers are focusing on cycling, because it is often seen as a key and relatively simple element in the solution of complex mobility problems, together with having a positive impact in other policy domains most notably public health (Oja et al., 1998). As Rutter et al. states "Increasing regular physical activity is a key public health goal. One strategy is to change the physical environment to encourage walking and cycling" (Rutter et al., 2013, 89). Although there are concerns about potential negative effects on health due to increased exposure to risk and air pollution, there is evidence that suggests that the benefits greatly outweigh this (De Hartog et al., 2010).

When cycling can be an important intervention to increase public health, and a variety of other domains it is of utmost importance to improve our understanding of how it can be increased. Often, the Netherlands is referred to as the gold standard for bicycle use and bicycle

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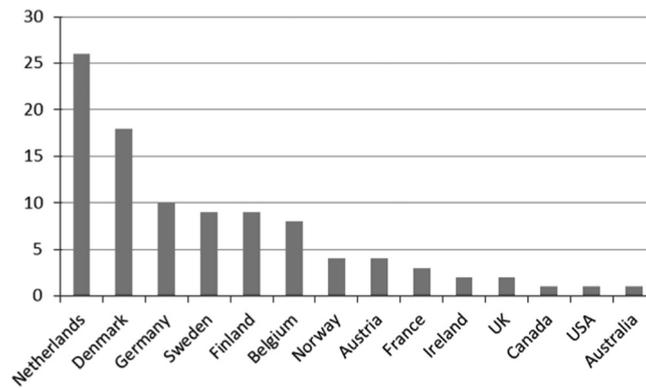


Fig. 1. Share of cycling as percentage of all trips in 14 countries (Pucher and Buehler, 2012).

policies. However, although the modal share for cycling is significantly higher than in other countries (Fig. 1) and the trend in urban areas is still more growth, very little is known about the dynamics that underpin this trend. More knowledge is needed on the spatial and social characteristics of cycling patterns and trends. Who is cycling more and who less? Where is cycling more popular and where less? How do these trends change over time? The answers to these questions can greatly enhance our understanding of the sensitivity of cycling to these different contexts and our capacity to develop policies that take this sensitivity into account (both in the Netherlands and abroad).

This paper explores the spatial and social differences in cycling levels and trends in the Dutch context. First, we discuss recent literature on the drivers behind differences and changes in mobility, with a focus on cycling. In the third section we discuss our methodological choices, after which patterns and trends for the different spatial contexts and social groups in the Netherlands are explored. The paper continues with a discussion of the findings and methodology (Sections 4 and 5), finally closing with a consideration of their implications for policymaking and further research.

2. Recent research on social and spatial differences and changes in cycling

According to Van Acker et al. (2010) travel behaviour is the outcome of spatial, social and individual opportunities and constraints. The first relates to the quantity and quality of infrastructure and the built environment. The second relates to socio-demographic, socio-economic and socio-cultural factors, like gender, age, income and ethnicity. The third includes personal socio-psychological factors like attitudes and perceptions. Based on the available data, in this paper we focus on the first two layers of travel behaviour determinants: spatial and social differences and trends (Fig. 2). First we will review the recent literature contributions regarding spatial and social differences in cycling, second we will look at recent insights on changes and trends in mobility patterns and cycling.

2.1. Spatial and social differences in cycling

Heinen (2011, 23–30) gives an extensive overview of the spatial context variables that influence cycling, with density of the built environment and the diversity of urban functions as particularly important (Pucher and Buehler, 2012, 13; Nielsen et al., 2013; Heinen, 2011, 25). According to most research higher density of built environment and diversity of urban functions correlate with shorter distances to destinations and consequently a higher probability of cycling. Apart from density and diversity, the design of infrastructure and the urban landscape are also frequently mentioned: cyclists prefer separate bicycle lanes over roads with curb lanes or roads without any bicycle facilities (Heinen, 2011, 25) and prefer high levels of connectivity (e.g. an integrated network of cycling lanes; Titze et al., 2008). Stop signs and traffic lights can also cause irritation due to delays and the additional physical effort needed for stopping and accelerating (Fajans and Curry, 2001). Another design-related factor is the attractiveness of the built environment along cycling routes, with some authors suggesting that it has a positive effect on cycling levels (Gatersleben and Uzzell, 2007; Southworth, 2005).

As far as social context variables are concerned, Garrard et al. (2012) and Bonham and Wilson (2012) found that a large part of social variations in cycling behaviour can be traced back to basic demographics, like age and gender. International comparative studies found that as the cycling share increased, the differences in cycling between men and women decreased (Garrard et al., 2012, 215; Bonham and Wilson, 2012, 60). In countries with low overall cycling levels the majority (around 80%) of cyclists are male. In contrast, countries with relatively high cycling levels seem have more equally distributed cycling rates between men and women. The same holds true for age differences: the higher the cycling share in total trips, the smaller the differences between age groups. Overall, in countries with low cycling rates, mostly young adult men are cycling (especially for recreational purposes), whereas in places with high cycling rates children and the elderly are also cycling more, and utilitarian purposes are more important (Garrard et al., 2012; McDonald, 2012). Another demographic variable mentioned in the literature is household composition and activity patterns: According to research findings originating from countries with low cycling levels, having young children reduces the probability of cycling (Heinen, 2011; Ryley, 2006).

Apart from demographic aspects, socio-economic indicators (like income) also influence mobility levels, but as demonstrated by Heinen (2011) their relationship with cycling is unclear. In her analysis, she distils two opposing effects. First, people from higher income brackets can spend more money on a bicycle, which in turn increases cycling rates. This effect seems to be especially true for countries with a low overall cycling share, for example, the United States and Canada (Pucher and Buehler, 2008). Second, higher income also translates into higher car ownership rates, which has a strong negative impact on cycling levels. Pucher et al. (2011, 455) found that overall bicycling rates do not vary much with income levels in countries with high cycling levels. However, the motivation to use bicycles is different. Low-income individuals usually cycle for utilitarian reasons, while high-income individuals cycle more often for recreation and exercise. Another socio-economic aspect is education levels. Heinen (2011) finds a negative relationship between education levels and

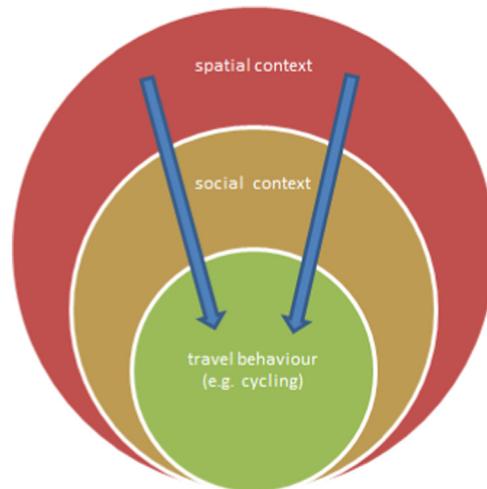


Fig. 2. Spatial, social and individual determinants of travel behaviour (adapted from Van Acker et al., 2010).

cycling: people with high education levels cycling less. On the other hand, research from the United States indicates that the cities with higher portions of educated inhabitants are also the cities where people cycle the most ([Handy et al., 2010](#)).

A socio-cultural aspect that influences cycling levels is ethnic background. Research findings from the United States indicate that migrants are more likely to travel by bicycle than native-born citizens, some of them due to financial barriers to car use (low incomes) and the associated legal risks (usually lacking car insurance or proper documentation) ([Garni and Miller, 2008](#), 446; [Smart, 2010](#), 5). Other explanations are spatial clustering of migrant groups in urban areas, which shortens trip distances and encourages bicycle use ([Smart, 2010](#)). [Pucher et al. \(2011, 455–456\)](#) found that cycling rates in the United States during the 2000s rose fastest among African Americans, Hispanics and Asian Americans. On the contrary, in countries with high cycling rates, people with a migrant background seem to cycle less. Earlier research carried out by the Netherlands Institute for Social Research (SCP) showed that people with a migrant background travel less often and shorter distances. They use cars and especially bicycles less frequently, relying instead on public transport ([Harms, 2007](#)).

2.2. Spatial and social trends in cycling

Most of the existing research focuses on determinants of cycling use at one moment in time. Research on changes and trends in cycling is underrepresented. Nonetheless, based on the literature on changing mobility patterns in general and the recent discussion on ‘peak car’ and changing travel behaviour of young adults in particular (see [Goodwin and Van Dender, 2013](#)), we present three aspects of changes in mobility patterns that might have implications for cycling.

The first aspect is changes in population size and its spatial distribution ([Goodwin and Van Dender, 2013](#)). It is noted that there are diverging trends in mode use within countries, notably between the largest cities and rural regions. Based on data for the UK, [Headicar \(2013\)](#), for instance, shows that the levels of car use are lower in larger or denser settlements than in smaller or less dense ones, and notes that this gap is widening over time. He relates these differences to the growth of urban populations and the declining share of people living in rural areas (further exasperating the difference in population density). The effect of this trend is compounded by investments in cycling and public transport, and restrictions on traffic and parking space in cities ([Grimal et al., 2013](#)).

A second aspect is changes in population characteristics, for example, the shares of the different age-groups (see [Haustein et al., 2013](#)). One visible trend is the aging of the population: in the coming decades the elderly population of most developed countries will double, as the so-called baby boomers age into their 1970s, 1980s and 1990s. This demographic shift will have an important impact on mobility patterns and mode use, as older people travel less often, over shorter distances and for different reasons than younger adults. Therefore, overall demand for mobility will fall (e.g. [Haustein et al., 2013](#); [Metz, 2013](#)) and the characteristics, timing and spatial orientation of trips (car and cycling) will change considerably, with less emphasis on work-oriented trips and more on recreational use (see [Haustein et al., 2013](#); [Metz, 2013](#)). Other examples of demographic effects on mobility levels are the growing number of single-person households and the growing share of immigrant groups, which induce more and less cycling, respectively (e.g. [Harms, 2007](#)).

Third, besides population distribution and population composition, changes in cycling levels are also determined by changes in travel behaviour, e.g. trips per capita and trip distances in the same population group ([Goodwin and Van Dender, 2013](#)). The change in young adults’ travel patterns is one example: in North America and many West-European countries they seem to shift away from using cars in favour of public transport and cycling (see [Kuhnimhof et al., 2011](#); [Van der Waard et al., 2013](#)). The literature suggests various explanations for these changing patterns. Some associate this shift to changes in the youths’ perception and experience with cars, related to rising costs of owning and using a car, growing environmental concerns, and a preference to live in less car-dependent suburban and more walkable and transit oriented urban communities (see [Litman, 2012](#)). Other explanations mentioned include the changes in the transition into adulthood. Based on a European comparative study, [Billari and Liefbroer \(2010\)](#) conclude that both cohabitation and childbirth are postponed (or do not occur at all), which reduces the chance of moving to the suburbs and adopting car-dependent lifestyles ([Metz, 2013](#)). There are visible changes in travel behaviour among the elderly as well (e.g. [Haustein, 2012](#)). Research findings from the Netherlands suggests that compared to previous generations, baby boomers use cars for journeys more often, increasingly do so as the driver, and continue to do so at ever-increasing ages. Cycling seems also to be relatively more popular, but public transport is used less frequently ([Arentze et al., 2008](#)). In other words, the overall mobility reducing effect of an aging society might be (partly) compensated by more per capita cycling and car trips of the elderly.

2.3. Conclusions

Based on the recent literature on cycling it seems important to distinguish between spatial characteristics like density, diversity and design of infrastructure and the built environment; and social characteristics such as the socio-demographic, socio-economic, socio-cultural determinants of bike use. A first limitation is that most of the findings on how these variables influence cycling levels refers to data originating in countries with overall low cycling shares like the United States and the United Kingdom. Few studies look at countries with high cycling shares, and they provide little or outdated insights into social and spatial disaggregation of cycling. A second (and maybe more important) limitation of existing research is the lack of insights on changes and trends in cycling. However, based on the wider literature on mobility trends, three factors can be distilled which seem to be important in this respect: changing population volumes and spatial distribution of the population, changing population composition, and changing travel behaviour. In order to address the first two limitations, we will examine below how spatial and social characteristic affect cycling levels and trends as well as changes through time in the Netherlands, a mature cycling nation. We will continue by discussing the data used and the methods applied; then we will look at the spatial and social differentiation of cycling levels, and finally we will focus on cycling trends and changes.

3. Data and methods

3.1. Data

The National Travel Survey (NTS) of Statistics Netherlands (CBS) is an extensive and specialized survey on the mobility behaviour of the Dutch population. It provides data on the number of trips, travel time, distances covered and transport modes, broken down by different trip purposes as well as social and spatial characteristics of the travellers. Respondents are asked to keep a diary for a specified day and record all their trips, including specific features, such as the transport mode being used, origin and destination, time of departure and arrival, and trip purpose. In this paper we use data from 2010 and 2011 to get insights into current social and spatial differences in cycling patterns, and we use comparable NTS data for the period between 1985 and 2009, to look at trends and changes. Because of the substantial sample size, the database can be easily disaggregated along social and spatial characteristics, although the reliability of the data decreases by zooming in socially and spatially, and due to the variety in survey samples per year¹: For this reason, we decided to pool data for a selection of years (indicated in the tables and text).

The NTS-data provides a very detailed overview of mobility (trends) of the Dutch population, but when interpreting the results one should be aware of the fact that the data is not always entirely reliable or complete. First of all, although most of daily mobility in the Netherlands is covered in the NTS-data, its completeness cannot be guaranteed due to underreporting of some selected journeys (e.g. very short walking trips or holiday trips) or selective non-response for some segments of the population such as ethnic minorities or children. Second, the data may suffer from systematic biases due to mistakes made when filling in a journey diary (e.g. journeys might be forgotten or the distance travelled is estimated incorrectly). Third, the results might suffer from sampling errors because data is based on a fraction of the population. Although very small differences are albeit almost statistically significant due to the large sample sizes² (see above), selectiveness or random fluctuations might still result in errors (not reflected in the statistical tests).

As a result of the complications with interpreting the results of the NTS-data, we used confidence intervals (reliability margins) around our outcomes for cycling trips at $\pm 10\%$, which is in accordance to calculations from the Netherlands Institute for Road Safety Research (SWOV)³.

3.2. Method and variables

To explore social and spatial differences in cycling patterns, we have used descriptive bivariate statistics. In addition and whenever necessary we used multivariate statistics, which adjusts the bivariate relation between two variables for underlying, intervening variables. More precisely, we used the multivariate analysis of variance statistics procedure in SPSS, which controls the variance in a dependent variable (e.g. cycling share) caused by an independent variable (e.g. a social or spatial characteristic) for the variance caused by other independent variables (e.g. because of correlation between social or spatial characteristics). We have indicated in the tables and text where we applied multivariate statistics and specified which variables were controlled. To describe cycling patterns, we looked at both aggregated volumes of cycling trips as well as individual (per capita) cycling trips, cycling trip distances and cycling shares. Whereas per capita cycling figures are directly derived from the NTS data, we calculated aggregate cycling volumes by multiplying per capita figures from the NTS data by population totals (for various social or spatial subgroups) based on data from Statistics Netherlands (CBS).

Regarding the spatial and social differences, the NTS data allowed us to distinguish between many of the spatial and social indicators described in Section 2. For the spatial differences in cycling levels we used the urban density categorization developed by Statistics Netherlands (CBS) of five classes of urbanization according to the number of residences and work places per square kilometre: very highly urbanized areas (more than 2500), highly urbanized areas (1500–2500), moderately urbanized areas (1000–1500), less urbanized areas (500–1000), and not urbanized or rural areas (less than 500). For social differences we were able to distinguish between socio-demographic variables like age, gender, and household structure; socio-economic variables like income and education level; and socio-cultural variables like immigrant status.

To explore the trends, we have differentiated between changes that can be attributed to population growth and distribution, changes in population composition, and changes in per capita trips and distances. We have disentangled these effects by presenting both aggregate volume changes (for various groups and spatial aggregates) and per capita changes. The effects of population growth and distribution and population composition were estimated by assuming that per capita behaviour for the various spatial and social segments remained unchanged. In other words: changes in aggregate cycling volumes are derived by keeping per capita behaviour constant and multiplying these figures with changes in population size, distribution or composition. Of course this assumption has been checked upon by also looking at actual per capita changes.

Finally, whenever possible and meaningful, we differentiated between the various utilitarian and non-utilitarian travel motives: commuting to/from work, cycling to/from school, and shopping and recreational trips.

¹ In both 2010 and 2011, a total of 30,000 respondents filled in a diary. For the 1985–2009 period, the total number of respondents per year varied greatly (from a minimum of 23,900 in 1991 to a maximum of 167,900 in 1995).

² Note that due to the large sample sizes levels of variance are very small, which means that differences between two sample fractions are albeit almost statistically significant. As a check we performed various *t*-tests (Isd, bonferonni) comparing all social and spatial differences in cycling and almost all showed to be statistically significant.

³ See SWOV (2014). Note that this is a very conservative and broad estimate. Most recent estimates for reliability margins for cycling as published by Statistics Netherlands (2014) are much smaller: $\pm 2.7\%$ (CBS, 2014).

Table 1
Share of cycling in total trips for various trip purposes and urbanization (NTS, 2010/2011).

	Bicycle share				
	Total	Work	Education	Shopping	Leisure
Total	27	25	46	29	23
Very highly urbanized	27	29*	40*	28	24
Highly urbanized	26	25	46	29	22
Moderately urbanized	28	25	47	32*	24
Less urbanized	27	23	47	28	25
Not urbanized	23*	18*	46	23*	22

Note: For all differences it has been checked if they are statistically significant (using various tests of significance as provided in SPSS-software). Due to the large sample sizes all differences are statistically significant. Nonetheless, in accordance to estimates used by the Netherlands Institute for Road Safety Research (SWOV) we used confidence intervals (or reliability margins) around our outcomes for cycling trips at $\pm 10\%$ (see also Section 3). In our results all differences (deviations from the overall mean) larger than $\pm 10\%$ have been marked with an asterisk (*).

4. Research results: Spatial and social differentiation in Dutch cycling

NTS-data for the years 2010 and 2011 shows that the bicycle mode share for the Netherlands as a whole is 27% of all trips. For trips to and from school, almost half of all trips are by bicycle; for work, shopping and leisure the bicycle share is approximately 25%. Below we will explore how these figures change according to spatial and social characteristics?

4.1. Spatial differentiation of cycling patterns

To explore the spatial differences in cycling levels, we have distinguished between 5 classes of urbanization (see also Section 3.2) from very highly urbanized areas (more than 2500 addresses) to not urbanized or rural areas (less than 500 addresses).

Based on this distinction the NTS-Data (NTS, 2010 and 2011) shows that people living in rural areas cycle less often than people living in urban areas (see Table 1).

When we control for trip purpose, some differences are amplified: cycling to and from work is most popular in very highly urbanized areas and least popular in rural areas, whereas for cycling to and from school the opposite is true. For shopping, the bicycle is used slightly more frequently in urban areas as compared to rural areas, while for recreation the differences in cycling share are minor.

4.2. Social differentiation of cycling patterns

Table 2 presents cycling shares for various social groups and trip purposes.⁴ Three noteworthy outcomes stand out:

First, gender differences in cycling in the Netherlands are very small and contrary to findings in other countries were cycling is less popular (and especially women are cycling less often). In the Netherlands women cycle more often than men, especially for trips to and from work and for trips related to shopping (Table 2).

Second, there are large differences in cycling by age (see Table 2). Young people cycle more often than older people: roughly a third of all cycling trips (32%) are generated by children and teenagers up to 18 years old. Teenagers cycle the most: more than half (55%) of all their trips and more than two-thirds (70%) of trips to/from school are on a bicycle. With age (50 years and older) the share of cycling and the frequency of cycling trips declines, but the distances covered are somewhat larger, especially for recreational purposes.

Third, people with a non-Western migrant background (either they or their parents were born in a non-Western country⁵) cycle less frequently than people born in the country (Table 2). This finding confirms earlier research (see Section 2), and holds true for all trip purposes and for all age groups, even more so after correcting for socio-economic differences (like income and education levels).

5. Research results: Spatial and social trends in Dutch cycling

Above, we focused on spatial and social differences in cycling levels. This section expands on these findings by taking into account differences in temporal trends, that is, changes in the identified social and spatial patterns through time. Looking at national averages, there are no significant changes: in the mid-1980s the share of total cycling trips was 25%. Currently the cycling share is still about one out of every four trips. This consistency is visible for all trip purposes: work-related trips cycling has a stable share of approximately 25%, for going to and from school it is roughly 50% (for 1985 and 2012 and all years in between), for shopping it is around 30%, and for leisure trips (e.g. visiting friends and family, recreation) one out of five trips is by bike. How do these average trends differentiate when taking into account social and spatial characteristics?

⁴ All results are the outcome of a multivariate analysis of variance, which means they have been adjusted for variance between independent variables (see also Section 3).

⁵ According to the official definition of Statistics Netherlands (CBS), non-western immigrants are people whose parents or who are themselves born in a non-Western country (e.g. Africa, Latin America or Asia, including Turkey and excluding Indonesia and Japan). The largest groups of non-western immigrants living in the Netherlands originate from Turkey, Morocco, Surinam or the Antilles. These four groups comprise together more than 60% of all non-western immigrants living in the Netherlands (2 million in 2013, which is roughly 10% of total Dutch population) (Statistics Netherlands).

Table 2
Share of cycling in total trips for various trip purposes and social groups (NTS, 2010/2011).

	Bicycle share				
	Total	Work	Education	Shopping	Leisure
Total	27	25	46	29	23
Men	25	22*	46	25*	24
Women	28	29*	45	31*	23
0–11 Years old	39*	N/A	36*	36*	34*
12–17 Years old	63*	73*	70*	56*	53*
18–29 Years old	21*	22*	38*	24*	20*
30–39 Years old	19*	21*	46	21*	16*
40–49 Years old	22*	23	48	29	18*
50–64 Years old	23*	27	39*	32*	19*
65–74 Years old	20*	22*	N/A	29	17*
≥ 75 Years old	13*	21*	N/A	19*	11*
Single-person household	28	24	56*	30	27*
Couple without children	25	24	35*	28	22
Couple with children	27	25	45	28	23
Lone-parent with children	26	24	43	29	24
€ 10.000–20.000	28	28*	45	29	25
€ 20.000–30.000	26	24	42	28	23
€ 30.000–40.000	26	27	45	27	21
€ 40.000–50.000	27	23	46	31	23
€ 50.000 or more	26	23	47	29	25
Lower education levels	27	26	36	28	25
Medium education levels	24*	23	36	27	23
Higher education levels	27	25	35	31	25
Native Dutch background	28	26	48	30	24
Western migrant background	25*	23*	46	27	22
Non-Western migrant background	18*	14*	34*	19*	16*

Note: For all differences it has been checked if they are statistically significant (using various tests of significance as provided in SPSS-software). Due to the large sample sizes all differences are statistically significant. Nonetheless, in accordance to estimates used by the Netherlands Institute for Road Safety Research (SWOV) we used confidence intervals (or reliability margins) around our outcomes for cycling trips at $\pm 10\%$ (see also Section 3). In our results all differences (deviations from the overall mean) larger than $\pm 10\%$ have been marked with an asterisk (*).

5.1. Spatial trends in cycling patterns

Based on NTS data from 1994 onwards (the first year that urbanization rates are available), we successively looked at the effects of changing population size and population composition on aggregate cycling volumes and per capita cycling behaviour.

5.1.1. Changing population size and composition

From the 1994 to 2012, the share of people living in urbanized areas increased from 39% to 48%, whereas rural populations declined from 39% to 32% (NTS, 1994–2012). This so-called re-urbanisation (see Section 2) is associated with growing cycling volumes in urban areas and a decline of overall cycling volumes in rural areas. Assuming that per capita cycling behaviour remained unchanged, re-urbanisation has resulted in a 22% growth of cycling volumes in urban areas (to 1.4 million daily trips), whereas in rural areas the cycling volumes have declined by 9% (to 0.5 million daily trips, Fig. 3).

These changes are exacerbated by the changes in the relative shares of young and elderly people (who respectively cycle more and less frequently than average). In more urban areas the proportion of teenagers and young adults has been growing, especially in recent years, whereas the proportion of elderly people is growing in less urban areas. On the other hand, urban areas in particular have a growing share of people with a non-Western migrant background, which might have dampened the growth of cycling levels there. A more spatially disaggregated analysis is needed to disentangle the effects of the changing population composition within urban and rural areas.

5.1.2. Changing per capita cycling

Apart from changing population distribution and composition, changes in cycling levels are also influenced by per capita changes in mobility. Although our analysis does show some changes in per capita levels within urban and rural areas, the effects are rather small and should be interpreted with caution due to data reliability issues⁶ (Table 3). Nonetheless, it seems that per capita cycling is increasing in both urban and rural areas for trips to/from school. Although apparently not significant, for all other trip purposes the share of cycling seems to be increasing in urban areas, whereas in rural areas the opposite is true. The Netherlands Institute for Transport Policy Analyses

⁶ Per capita changes in urban and rural cycling rates might be caused by cohort effects or individual behavioural changes, but also other interfering factors might dilute the results, such as urbanization of municipalities which causes them to shift from rural to urban. We have corrected as much as possible for this by combining urbanization classes (very highly urbanized, highly urbanized and moderately urbanized have been combined as urban areas, whereas less urbanized and not urbanized have been combined as rural areas) and combining the outcomes of the NTS data for several years (1994 to 1996 and 2007 to 2009) thereby limiting variations caused by factors not related to changes in bicycle use.

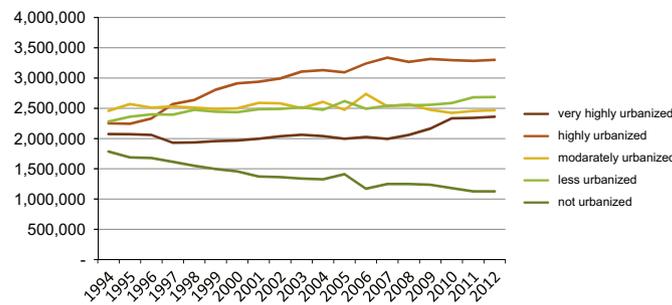


Fig. 3. Cycling volumes in urban and rural areas 1994–2012 (NTS, 1994–2012).

Table 3

Changes in bicycle share according to urbanization rate 1994–2009 (NTS, 1994–2009).

	Urban		Rural	
	1994–1996 (%)	2007–2009 (%)	1994–1996 (%)	2007–2009 (%)
Cycling share				
All trips	25	27	27	25
Work related trips	26	27	23	21
Education related trips	39	47*	44	50*
Shopping related trips	27	29	31	28
Leisure related trips	21	22	24	22

Note: For all differences it has been checked if they are statistically significant (using various tests of significance as provided in SPSS-software). Due to the large sample sizes all differences are statistically significant. Nonetheless, in accordance to estimate used by the Netherlands Institute for Road Safety Research (SWOV) we used confidence intervals (reliability margins) around our outcomes for cycling trips at $\pm 10\%$ (see also Section 3). In our results all differences (deviations from the previous years) larger than $\pm 10\%$ have been marked with an asterisk (*).

(KiM) have signalled more cycling to/from school to a simultaneous decrease in walking, which they relate to an increase in the distances to the nearest educational facilities (e.g. less facilities, located further away), especially for those living in rural regions (KiM, 2013). This is illustrated by the fact that average trip distances to/from school have increased from approx. 5 km in the mid-1990s to approx. 7 km in 2007).

5.2. Social trends in cycling patterns

To disentangle aggregate trends according to social groups we used NTS data from 1985 onwards (in contrast to spatial trends, for which data is available from 1994 onwards, see Section 5.1). As with the spatial trends we successively looked at the effects of changing population numbers and population composition on aggregate cycling volumes and at changes in per capita cycling behaviour.

5.2.1. Changing population size and composition

Trends in aggregate cycling volumes are predominantly shaped by shifts in population size and composition. First of all, the population has been growing by 13% since the mid-1980s, which would mean, all the rest being equal, 13% more cyclists.

Second, the age composition of the population has changed considerably (Fig. 4). The proportion of teenagers and young adults has declined (respectively from the mid-1980s and the early 1990s), whereas the proportion of elderly has been growing. Since the two younger groups account for higher than average cycling levels, this has resulted in a reduction of both overall cycling volumes and kilometres. An increase in the elderly population resulted in a rise in the number and kilometres of recreational bike trips. At the same time, the growing proportion of people aged 40 to 60 years has fuelled total cycling volumes, especially work trips. This has partly been offset by a decline in the size of the 30- to 40-year-old cohort.

Third, the share of immigrants has been growing, especially people originating from non-Western countries: in the mid-1980s the Netherlands counted 650,000 non-western immigrants (5% of the total population), currently they number almost 2 million (11% of the total population) (CBS, 2013). The population shares are especially high amongst the younger cohorts and urban areas, sometimes reaching levels over 60% (CBS, 2013). Considering the low cycling shares of these groups (see Table 2), this growing proportion of ethnic minorities in total population has had a dampening effect on overall cycling levels.

5.2.2. Changing per capita cycling

An overview of trends in per capita cycling shares by age reveals minor changes between the mid-1980s and 2007 (Fig. 5). Only for young adults (15–24 years old) and elderly (aged 65+) has the share of cycling increased. For more recent years we do not have reliable data available on per capita travel behaviour trends, although estimates by the Netherlands Institute for Transport Policy Analysis (KiM, 2013) suggests that per capita distances seem to be growing somewhat, which might be entirely attributed to more people (predominantly the elderly) using electric bikes (e-bikes): Based in the latest available NTS-data from Statistics Netherlands it is estimated that 12% of the Dutch population owns an e-bike, the majority of which are 65 years and older. For people aged 65+ the e-bike is estimated to account for more than a third of all cycling kilometers; for younger cohorts the e-bike share is only 2% for adults aged up to

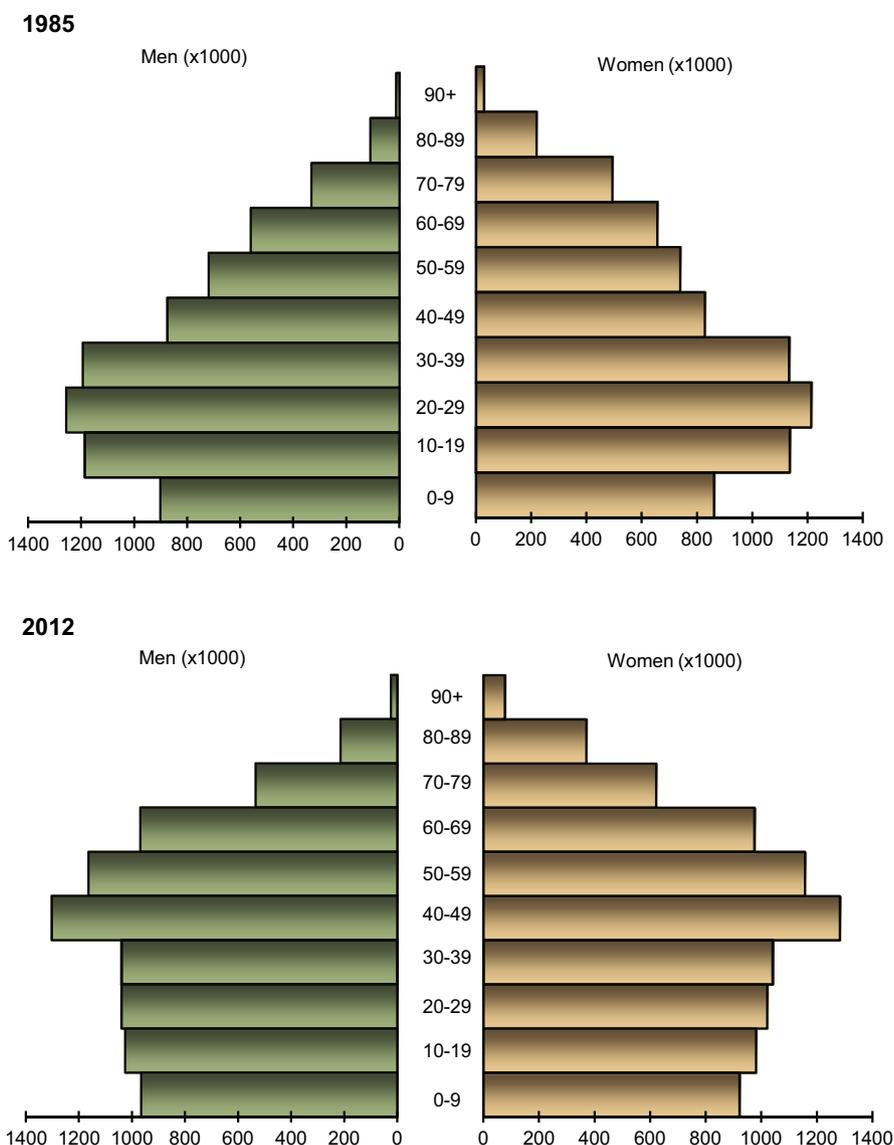


Fig. 4. Age composition of the Dutch population in 1985 and 2012 (CBS, 2013).

35 and 6% for adults aged to 50 years (for more about e-bike use in the Netherlands and its possible implications, see Jones et al., submitted for publication). Besides the effect of more e-bike use for the elderly cohorts, conventional per capita cycling behaviour seems not to be changing. However, if we have a closer look and disaggregate trends to various trip purposes, three changes are still notable.

First of all, the share of cycling for teenagers has been increasing slightly and remained the same for young adults. For young adults living in urban areas cycling shares have increased whereas car use has declined, which is in accordance to findings in other Western countries (see also Section 2.3; Kuhnimhof et al., 2011; Van der Waard et al., 2013).

Second, whereas overall cycling shares for adults between 25 and 65 years remained the same (Fig. 5), the use of the bike for work-related trips has increased. This is especially true for women, whose increased labour market participation has translated in more per capita bike trips.

Third, contrary to earlier elderly generations, the baby boomer cohort (currently aged 65 and over) is cycling more frequently, mostly for recreational purposes. The trip distances have not changed much,⁷ but the frequencies have substantially increased (leisure trips have increased by 30% since 1999) and with them also overall cycling kilometres. On top of the demographic effect of the growing group size, cycling levels for the elderly have shown a greater increase because of lifestyle effects: older people are more active and participate in more leisure activities outside the home.

Finally, it is conceivable that subsequent generations of ethnic minorities have adopted different mobility patterns that resemble native Dutch behaviour (e.g. more cycling). However, even though the NTS does not provide comparable data on the travel behaviour for ethnic minorities, there are no indications that the behavioural differences found in earlier studies (e.g. Harms, 2007 based on other data collected in 2005) are changing. This can be seen for instance by comparing the age differences in cycling rates (derived from the NTS data

⁷ At least until 2007, but according to estimates of the Netherlands Institute for Transport Policy Analysis it has been growing in more recent years, mainly due to more elderly people using e-bikes (KiM, 2013).

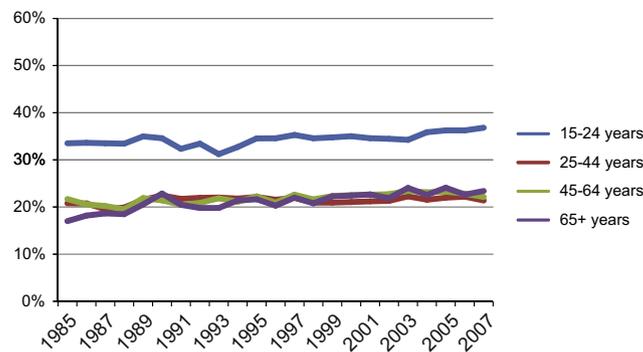


Fig. 5. Changes in cycling share by age 1985–2007 (NTS, 1985–2007).

from 2010 and 2011): differences in cycling levels between young people with a migrant background and their peers from the native Dutch background are as large (or even larger) than differences in cycling rates for older age cohorts.

6. Conclusions and discussion

6.1. Spatial and social divergence of cycling patterns

This paper started from the notion that cycling is considered a powerful policy intervention to increase public health in many cities around the world. Often, the Netherlands is seen as the example case of how this can be achieved. However, there is limited generalizable knowledge about the underlying patterns and trends in this country. Such insights are needed to ensure valuable policy transfer to other contexts. Next, the paper explored spatial and social differences as well as changes and trends in cycling patterns in the Netherlands. This analysis built on spatial and social determinants of cycling that are generated by studies in countries with overall low cycling shares.

Through an analysis of NTS data, we found a number of spatial and social differences in cycling patterns in the Netherlands. First, people living in urban areas cycle slightly more often than people from rural areas, albeit the difference is not very large, and the share of cycling does not increase proportionally with urbanization: moderately urbanized areas have a similarly higher share of cycling (see Table 1). Second, young people (up to 18 years of age) cycle more often than older people: roughly a third of all cycling trips (32%) and a quarter of cycled kilometres (27%). Third, people with a non-Western migrant background (either they or their parents were born in non-Western country) cycle less frequently and cover shorter distances than people born in the country.

Regarding trends, our main finding is that changes in cycling patterns seem to coincide with quite dramatic changes in the spatial distribution of the population: more people are living in urban areas where cycling is often a fast and convenient mode for reaching many destinations. A second finding is that, although cycling behaviour within age groups remains remarkably stable, overall cycling levels are influenced by changes in the composition of the population, of which the growing share of elderly people and immigrants is particularly important. Third, although per capita changes in cycling are minor, young adults living in urban areas are cycling more often. Elderly people are cycling more often as well, which is partly enabled by the increasing popularity of e-bikes. Taken together these changes both point at factors enhancing and factors hampering cycling (resulting in a relatively stable overall cycling level). Whether this trend persists into the future will largely depend on the relative rate and direction of change in these factors. Will the spatial distribution of the population change at a higher rate than its composition, or will the reverse be the case? Will per capita changes in specific population groups accelerate, decelerate or possibly even change direction?

6.2. Discussion and implications

Relating to the envisioned health impact of cycling policies, this analysis paints a more nuanced picture than the ones that are often shared about the Netherlands. Although there are indications that differences in policies have effects, the patterns and trends shows that spatial and social contexts matter a lot for the receptivity for such policies. The elderly appear to be an ideal target group, since cycling links very well to their increased mobility and resurged attention for personal health. Similarly young people, especially in urban areas, form a fertile ground to increase cycling and gain health benefits. However, the transition of young adults into parenthood seems an important negative turning point. As suggested by Rutter et al. (2013), it might just be that in terms of health impact, we need to turn first to our land use planners. The density and variation of activities (i.e. compact urban cities) seem to influence its chances for sustainable and healthy mobility patterns. At least, it seems wise to lower some of the expectations of interventions in the transport domain in terms of their impact in the Dutch case.

The analysis shows that changes in population size mainly explain changes in cycling volumes in rural areas (decreasing) and in urban areas (increasing). In the long term, cycling in rural areas may decline even more because of decline in supply of- and therefore access to facilities and services. Traveling longer distances to fulfil basic needs (which is already a reality for some groups and some motives), might result in an even stronger reliance on car use and less cycling. Perhaps e-bikes, with the extended range they provide, could make biking more appealing in rural areas. Meanwhile, in urban areas, the growing cycling volumes will need to be accommodated. Providing extra infrastructure for cyclists might be useful, but it is not always sufficient in itself. In some cases increases in cycling volumes are such that a more fundamental reconsideration of the allocation of street space for the different urban transportation modes (cyclists, pedestrians, cars and public transport) might be needed.

In general, the research outcomes stress the need to make existing and new policy measures more sensitive to the specific socio-spatial circumstances. The challenge is to develop policies that can sustainably mitigate the socio-spatial, context-specific threats and seize the opportunities for improving cycling shares.

6.3. Critical review and future research needs

In this paper we used NTS data to explore differences as well as trends and changes in cycling in a mature cycling country, the Netherlands. Although the cross-sectional NTS data is based on very large samples, when comparing cycling levels over different years for various geographical subzones, significant temporal and spatial variations remain. This hampers the disaggregation between the effects of changing population volumes, changing population composition and per capita changes. Furthermore, the lack of detailed data for certain social groups or social behavioural aspects is a problem. In the analyses we focused predominantly on spatial and social context variables, excluding individual characteristics, such as changes in attitudes and habits or perceptions. Additional insights like these could be based on longitudinal surveys or qualitative research tools in which the same persons or generations are followed over time. This could also help in explaining some of the trends and disentangling the interconnectedness and causality between social and spatial aspects. An example is the issue of 'residential self selection', meaning that certain people might rent or buy a house at a location which fits their mobility needs thereby determining overall cycling levels (e.g. [Bohte et al., 2009](#); [Cao et al., 2009](#)). More qualitative tools might also be used to consider the social relevance and meaning of cycling for different population groups and different areas, which has been suggested in some studies looking at cycling in the UK (e.g. [Aldred, 2010](#), [Guell et al., 2012](#); [Steinbach et al., 2011](#)). Other research could focus on the effectiveness of policy measures within the given spatial and social context. Which policy measures are successful in stimulating cycling in specific contexts and which are not? How could these policy measures be transplanted to other socio-spatial contexts without losing their effectiveness?

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