Effects of e-bikes on bicycle use and mode share

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Abstract

In Norway, as in many countries, a political goal is to increase bicycle use, and the e-bike is promising in this respect. However, concerns have been raised about mode-share effects. It has been argued that if the e-bike's only function is in cycling becoming cycling with electric assistance, there would be no benefit to either the environment or public health. Little is yet known about the use of the e-bike, or of its potential in reducing motorized travel. In the current study, 66 randomly selected participants were given an e-bike to use for a limited period of time and the results compared with those of a control group (N=160). E-bike cycling trips increased from 0.9 to 1.4 per day, distance from 4.8 km to 10.3 km and, as a share of all transport, from 28% to 48%, whereas with the control group there was no increase in cycling. The effect of the e-bike increased with time, indicating a learning effect among users, and was greater for female than for male cyclists. There were no differences with age. Overall, the results suggest that the e-bike is indeed practical for everyday travel.

Keywords: experiment; bicycling; public health; gender

1 Introduction

1.1 Background

Bicycling is associated with health, environment, efficiency and life quality benefits, (OECD/ITF, 2013) and the European Commission (2011) acknowledges its importance as an integral part of future urban mobility and infrastructure design. In Norway, the political goal is that all future growth in urban mobility is absorbed by the sustainable transport modes of walking, cycling and public transport. More specifically, the aim is for 8 percent of all transport to be by bicycle by the year 2023, which will necessitate a bicycle market share of between 10 and 20 percent in the largest cities (Ministry of Transport and Communications, 2012).

At present, the share of bicycling in Norway is just under 5 percent (8 percent in summer and 1 percent in winter), and it is stable or declining rather than rising. Among youth, cycling declined from 15 percent around 1990 to 9 percent in 2010 (Vågane et al., 2011). Total overall cycling shares in the neighbouring countries of Sweden, Finland and Denmark are approximately 10, 11 and 18 percent, respectively (Pucher and Buehler, 2008b), and suggest that there is unexploited potential for increased cycling in Norway. The large proportion of short car trips in Norway, as well as in other European countries, is a further reflection of this (Pucher and Buehler, 2008a). Car journeys of less than 3 km account for 30 percent of all car trips and 46 percent of these are over less than 5 km. It has been estimated that 35 percent of all short trips by car could potentially be by bicycle (Lodden, 2002).

The e-bike (also called pedelec or EPAC) is promising in respect of increased bicycle use. It has an integrated battery augmenting the pedal-power of the rider and, in Europe, legally classified as a bicycle if it fulfils certain criteria, one of which is a maximum speed limit of 25 km h^{-1}. The e-bike is considerably heavier than an ordinary bike because of the battery and is hard to pedal when the battery is switched off or flat. Energy efficiency is better than that of any other mode of transport (except a traditional bike) – even walking! The e-bike is therefore environmentally superior to other motorized modes of transport (Dave, 2010; Wiederkehr, 2012). Giving the sensation of cycling with a tail wind or slightly downhill, the e-bike is quicker, it enables longer trips over hilly routes and it is an alternative for people who for various reasons are averse to bicycling. Compared to local public transport and rush-hour driving, the e-bike offers competitive travel speeds. Clearly, it has the potential to replace many car and public transport trips, all to the benefit of the environment, public health and other motorists.

In Asia, there has been a large increase in sales of e-bikes (Wu et al., 2012) and in Europe even more so. From 2006 to 2012 annual sales of e-bikes in Europe grew from just under 100 000 to 1 000 000 (www.colibi.com), with Germany, the Netherlands and Switzerland the largest markets. In Norway, e-bikes occupy a very small share of the market, whereas official sales statistics show that more than 400 000 traditional bicycles are sold annually. With only 5 million inhabitants, this puts Norway at the top in Europe when it comes to bike sales per capita (www.bike-eu.com). Official statistics for e-bikes are hard to come by, but it has been estimated

by industry representatives that around 1 percent of annual bicycle sales are of e-bikes (www.bike-eu.com).

Despite the large increase of e-bike sales in many countries, little is yet known about their use or of the effect they are having on motorized travel. Concerns have been raised that e-biking will, at best, only replace other non-motorized travel, i.e. cycling and walking. A Dutch study has shown that e-bike users cycle on average 30 km per week compared to the 18 km per week of normal cyclists (Fietsberaad, 2013). However, because this study did not provide information on people's travel behaviour prior to their acquiring an e-bike, we do not know whether it was the e-bike itself that brought about an increase in cycling, or whether these people cycled more than others prior to purchase.

Neither have previous studies of e-bikes assessed their mode-share effects. There has therefore been a call for studies controlling for other transport use in order to assess the effects e-bikes have on bicycling as a share of total transport (and not just total distance cycled), and also for studies testing the effects before and after the purchase of an e-bike (Dill and Rose, 2012). In assessing the causal effect of e-bikes, a randomised experimental study can function as proxy to a study of actual purchasers.

One particular issue that has been raised concerning bicycle use is the large gender differences in some countries. In cities or societies with poor infrastructure and low cycling shares, the majority of bicyclists tend to be male (Garrard et al., 2008). In places with higher shares, the gender balance is more equal, with some researchers proposing that women can function as "indicator species" for bike-friendly societies (Baker, 2009). The reason for this gender imbalance is not known (Krizek et al., 2005), but it can be speculated that women, because of their less muscular strength, suffer more from challenging topography than men do, or that they perceive the risk of cycling differently (Emond et al., 2009). Hence, it is of interest to examine the different effects e-bikes have on males and females.

Sales figures indicate that the earliest adopters of e-bikes have been the elderly (Fietsberaad, 2013). Figures from the Netherlands suggest that e-bikes even out the differences in cycling habits among age groups. Whereas the average weekly distance cycled has fallen from 20 to 15 km when comparing the age groups <46 and >60 years for normal bike users, there are no differences across age groups for e-bike users (Fietsberaad, 2013).

From the point of view of health, any increase in active mobility is positive, and from the perspective of transport planning and sustainable mobility, the biggest challenge is in creating shifts in the most habitual types of travel, i.e. people's everyday commute. Creating lasting changes in travel habits has proved a major challenge (Eriksson et al., 2008). From a psychological perspective, habit strength is known to be among the strongest predictors of behaviour (Verplanken et al., 1998). In the current study, our aim is to distinguish the effects e-bikes have between commute and non-commute travel.

Any new technology or any new acquisition can be subject to a novelty effect. It is known that interventions can often have short-term effects that do not necessarily transform into long-term behavioural shifts. On the other hand, it is established that

experience of a transport mode following incentives or marketing initiatives is associated with positive attitudes (Donaghy, 2011), increased use (Taniguchi and Fujii, 2007) and long-term adoption (Jones and Sloman, 2010). Learning from consumption means that experience of a transport mode increases the propensity for its use over time. There is evidence that as more and more contexts and situations are discovered an e-bike replaces a bicycle (Dill and Rose, 2012). This process is likely to take time and therefore delay any increase in bike use, probably countering any novelty effect that might occur. It would therefore be of interest to learn whether length of the trial period influences the effect the e-bike has on travel behaviour.

1.2 Study objectives

The aim of the present study is to analyse the effect e-bikes have on cycling, both as absolute distance travelled and as share of total transport. More specifically, we hypothesize that:

1. E-bikes will increase the amount of cycling, expressed as both number of trips and distance cycled.
2. E-bikes will have a greater effect on female than on male cyclists.
3. E-bikes will have a greater effect on older than on younger cyclists.
4. E-bikes will have a greater effect on commuting than on leisure time travel.

Furthermore, we explore whether e-bikes have a greater effect the longer there has been access to them, or whether the opposite is the case, i.e. whether the learning effect is greater or less than the novelty effect.

2 Method

2.1 Participants and procedure

The study was conducted as a field experiment, with 30 000 members of the Norwegian Automobile Federation (NAF) contacted by email in June 2013 and invited to take part in a web survey about everyday travel. The sample was a random selection of members living in the counties of Oslo and Akershus (the capital region). NAF is the biggest consumer organization in the Nordic countries and 10 percent of the Norwegian population are members.

Those who responded to the questionnaire at T0 (N=5462) were given a short description of an e-bike, and asked if they were interested in trying it out. Approximately a quarter (1425) of the participants said yes to this. At a second contact point (T1), the willing participants were given a travel diary (see below), and 776 of the initial sample responded. Prior to receiving the diary, 220 had been randomly assigned to be part of the test group, and the remainder to a control group. The test group initially had a sample size of 120, but owing to a higher than expected dropout rate it was supplemented with 100 more participants in the middle of the trial period. We have data from 183 participants in the test condition and 593 in the control condition at T1; and from 66 and 160 participants, respectively, at T2.

The trial period lasted from 28 July to 17 October. Participants were invited to take part in groups in accordance with their own stated availability and to test the bike for a period of either 2 weeks (N=55) or 4 weeks (N=11).

Characteristics of those willing to take part in the trial, of those who actually took part, of the control group, and of the population in the main study from which they were recruited are given in Table 1.

Table 1 Background characteristics of those willing to participate in trial, test group (after drop-out), control group (after drop-out) and all participants in recruitment survey.

	Willing participant	Test group*	Control group*	All
% above 65 years	14	11	9	19
Mean age	49	47	46	52
% Female	30	34	27	31
% Employed	82	92	91	78
% Cycling for Exercise/recreation > 4 days a week	3	16	3	3
% Cycling for transportation > 4 days a week	14	30	20	12
N	1425	66	160	5462

*After dropout.

Mean age of the participants was 47 years, and 34 percent were female. Note several differences between the test and control groups and the participants in the main study in that these groups are younger and have a higher share in employment. All groups in this study have a gender imbalance, which again stems from the gender distribution in the membership base of NAF. A notable difference between the test group and the other groups is higher cycling activity, in particular exercise and recreation.

A separate questionnaire "diary" was designed to record all travel on the day immediately before the e-bike was taken into possession. The same from was sent to participants in the control group. After completing the questionnaire, respondents were told whether or not they had been selected to borrow an e-bike and test group members were given the address of the collaborating e-bike shop and asked to make an appointment within 5 days. At the shop, test persons were given brief instruction on how to operate the bike, but no instructions were given about how and when they were to use it. However, they were instructed that the bike should be used only by themselves (except for short trial trips by family and friends).

Towards the end of the trial period (on the last day), the respondents received a new survey containing, in addition to the diary, questions about the e-bike as well as some of the same questions from the first main survey. In order to validate the self-reported cycling distances, data from the built-in cycle computer (odometer) were recorded and matched with each individual's response data.

2.2 Survey items

All in all, respondents received three questionnaires. In the first (at T0), they were asked how far they had cycled as transport and how far as exercise (in kilometres) in the last week and on the last day.

The second questionnaire was answered at T1 and had a travel diary section starting with an explanation of the procedure for how to define a trip, i.e. the trip had to be associated with a travel purpose. The first question was whether the participant had travelled outside the home yesterday. Subsequent questions required answers about travel mode, trip purpose, distance and time spent in a matrix. Travel mode could be on foot, by bicycle, e-bike, moped/motorbike, public transport, private car. For trip purpose, 14 categories of travel were used, borrowed from the National Travel Survey (Vågane et al., 2011). The first matrix had a limit of 6 trips; those who had more than this could go on to another matrix and fill in more trips (maximum 12).

At T2 the respondents were given the travel diary anew and asked about weekly cycling activity (trips and kilometres).

At T0 and T2 there were questions about intentions, attitudes and norms towards cycling; more details about present cycling activity; present transport modes for daily travel; travel resources as well as some background information. These questions are not utilized here (except age and gender). An overview of the timeline and data collection procedure for the study is given in Table 2.

Table 2 Overview of data collection procedure and timeline

	T0	**T1**	**T2**
Period	*June*	*June/July*	*August-October*
Questionnaire items	Weekly cycling activity	Travel diary	Travel diary Weekly cycling activity
N Total	5462		
N Control group		593	160
N Test group		183	66

3 Analysis and Results

Data were analysed using PASW statistics 18. A matched sample containing respondents who answered all three surveys (T0, T1 and T2) was used for analysis.

Technical problems resulted in our being able to record odometer data for only 53 of the 66 participants. On average, these cyclists cycled 6.9 km per day in the trial period. Their self-reported distance for the final day was higher (10.3 km), as was their reported weekly distance divided by seven (9.7 km). Still, the correlation between self-reported kilometres (weekly transport cycling) and odometer records was quite strong ($r=0.60$, N=53, $p<0.0005$).

The effects of the trial are summarized in Table 3. Distance cycled per week is measured at T0 and T2, while all other measures are comparisons between T1 and T2.

Table 3 Descriptive statistics of study outcome measures in the control and test groups. First row percentage, last row numbers, all other rows as means with standard deviation in parentheses.

	Control group		Test group	
	T1	T2	T1	T2
Bicyclists %	24	20	30	52*
Number of trips	0.6 (0.93)	0.54 (1.03)	0.93 (1.66)	1.4 (1.51)*
Distance/week, km[1]	33.9 (45.1)	29.8 (40.9)	40.1 (58.6)	68 (60.9)***
Distance cycled/ day, km	4.1 (8.6)	3 (6.4)	4.8 (8.1)	10.3 (12.2)**
Total distance all modes/ day, km	25.4 (22.1)	22.4 (21.8)	26.7 (26)	22.2 (17.2)
Cycling as share of total distance	0.2 (0.35)	0.2 (0.36)	0.28 (0.38)	0.48 (0.46)***
N	160		66	

*<0.1

**<0.01

***<0.01

[1] Registered at T0 and T2.

Of the 58 participants in the test group who had registered a trip in their travel diary, 30 percent had used a bicycle before the trial (at T1) and 52 percent on the last day of the trial period (at T2). This difference was statistically significant (p= 0.08). In the control group, 24 percent had used a bicycle at T1 and 20 percent at T2 (see Table 3).

From T1 to T2, the average number of cycling trips fell from 0.6 to 0.5 in the control group, whereas in the test group it increased from 0.5 to 1.6. Distance cycled was slightly reduced in the control group, while increased measured both per week and per day for the test group.

A paired-samples t-test was conducted to assess whether the changes were significant in any of the groups. For the control group, there were no significant changes from T1 to T2, while for the test group there was a significant change in number of trips *(t(58) = –1.58, p=0.06)*; distance cycled last week [t(55) = –4.229 , p<0.001); distance cycled on the day of registration [t(58) =3.218, p=0.002); and on cycling as share of all transport kilometres [t(58) = 3.511, p<0.001).

The effects of the trial according to gender are summarized in Table 4. Distance cycled per week is measured at T0 and T2. All other measures are comparisons between T1 and T2. In the control group, there was an increase in number of cyclists, number of trips and in distance cycled for females, whereas there was a decrease for males. In the test group, the increased percentage of cyclists, number of trips and in distance cycled was greater for females than for males.

Table 4 Descriptive statistics and results of repeated measures ANOVA (F and p-values) of study outcome measures for females in the control group (N=33), males in the control group (N= 104), females in the test group (N=20) and males in the test group (N=36). First row as percentage, all other rows Means.

		Control group		Test group		Within subjects effect	
		T1	T2	T1	T2	F	p
Bicyclists %	Female	0.25	0.31	0.14	0.50	3.35	0.074
	Male	0.21	0.15	0.42	0.46	1.02	0.314
Number of trips	Female	0.67	0.90	0.29	1.43	5.17	0.027
	Male	0.58	0.42	1.30	1.38	0.10	0.755
Distance/week[1]	Female	22.85	28.33	16.50	42.50	3.69	0.060
	Male	37.46	30.21	53.28	82.22	16.16	<0.001
Distance / day	Female	3.36	5.03	0.71	11.19	9.96	0.003
	Male	4.36	2.39	7.11	9.73	5.83	0.017
Cycling share	Female	0.20	0.28	0.11	0.37	2.32	0.133
	Male	0.20	0.14	0.34	0.55	10.66	<0.001

[1] Registered at T0 and T2.

In order to test whether the trial effects were influenced by gender, a one-way repeated measures ANOVA was conducted (separately for females and males) to test interaction effects of time × condition. The effect sizes were largest for women for *percentage of bicyclists* [F(1.58) 3.35 p=0.074], *number of trips* [F(1.58) 5.17 p=0.027], and *distance per day* [F(1.58) 9.96 p=0.0003], and for men *distance per week* [F(1.156) 16.16 p<0.001] and *cycling share* [F(1.156) 10.66 p<0.001].

The mean number of kilometres reported for both transport and exercise purposes in the last week prior to the response date for participants in the control and test groups are given in Table 5.

Table 5 Distance cycled for transport and for exercise last week at T0 and T2 for the control group (N=160) and for the test group (N=58). Kilometres (mean) and results of repeated measures ANOVA (F and p-values).

	Control		Test			
	T0	T2	T0	T2	F	P
Transport	19.9	22.3	26.5	48.0	10.85	0.001
Exercise	14.1	7.5	13.6	20.1	7.95	0.005

A paired-samples t-test showed that the reduction in cycling for exercise in the control group was significant *(t(159) = –3.19, p=0.002),* as was the increase in transport cycling in the control group *(t(57) =3.59, p<0.001).* A one-way repeated measures ANOVA was conducted to test interaction effects. There was a statistically significant time × condition interaction effect for both transport [Wilks Lambda = 0.95, F(1.191) 10.85, p=0.001] and exercise [Wilks Lambda = 0.96, F(1.191) 7.95, p=0.005].

The cycling activity at T1 and T2 for commute (to and from work/school) and non-commute purposes (any other reported purpose) of participants in the control and test groups is given in Table 6. Cycling activity is expressed either as mean number of kilometres or as cycled kilometres as a share of total commute or non-commute kilometres.

Table 6 Distance cycled for commute and for non-commute purposes on the day of registration at T1 and T2 for the control group (N=160) and for the test group (N=58). Kilometres (mean) and results of repeated measures ANOVA (F and p-values).

		Control		Test		Within subjects effect	
		T1	*T2*	*T1*	*T2*	*F*	*p*
Commute	Distance	2.3	1.9	3.3	5.7	5.64	0.03
	Km/total km	0.12	0.08	0.16	0.31	13.25	<0.001
Non-commute	Distance	1.8	1.1	1.5	4.6	13.17	<0.001
	Km/total km	0.26	0.23	0.34	0.66	9.37	0.002

A one-way repeated measures ANOVA was conducted to test the interaction effects. When measured as absolute distance cycled, the effect of the intervention is greatest for non-commute travel [$F_{(1.216)}$ 13.17, $p < 0.001$]. However, when measured as cycling as share of total commuting or non-commuting distance travelled, the effect is greatest for commute travel [$F_{(1.124)}$ 13.25, $p < 0.001$].

In order to test the effects of age, gender and test duration, as well as to provide estimates of adjusted effect sizes, we established a set of simple regression models. A number of different model specifications were tested and many rejected. The final models explain the variation in the dependent variable moderately well; four are presented in Table 7. For time period T2 they predict: (I) Total number of bicycle trips; (II) total number of commuting bicycle trips; (III) the share of mileage by bicycle of all trips; and (IV) the share of commuting mileage by bicycle. Test duration was included as a linear variable. Even although users were initially allowed to use the e-bike for two or four weeks, their test periods were in practice both longer and shorter than this, ranging from 9 to 64 days. Initial tests suggested that a linear relationship was appropriate. Test duration had a significant positive relationship with all the outcome variables.

Table 7 Model output. Dependent variables are (I) Total number of bicycle trips; (II) total number of commuting bicycle trips; (III) share of mileage by bicycle of all trips; and (IV) the share of commuting mileage by bicycle.

Dep.var (T2) / Indep.var	(I) Total No. of cycle trips		(II) No. of commuting cycle trips		(III) Bicycle mileage share of all trips		(IV) Bicycle mileage share of commuting trips	
	B	Sig	B	Sig	B	Sig	B	Sig
Y(T1)*	0.310	0.020	0.283	0.098	0.346	0.071	0.262	0.234
Test duration, days	0.057	0.003	0.028	0.028	0.022	0.001	0.027	0.003
Female Test User	0.738	0.100	0.510	0.082	0.065	0.650	0.235	0.235
Adj Rsq	0.507		0.408		0.508		0.565	

* Dependent variable in T1, i.e. previous period. For the first column, this would be total number of cycle trips recorded immediately before the test period.

Females responded more positively to the experiment in making more bicycle trips than men did. However, the proportions of total mileage by bicycle (models III) are not significantly different between men and women.

Age turned out to have no explanatory power. Clearly, a linear relation between bicycling and age is unlikely; model specifications comparing age groups failed to provide any significant relationships. *Age* was therefore removed from the models.

4 Discussion

We found that cycling among e-bike test users increased considerably (expressed as number of trips, distance cycled and as cycling shares) compared to the control group. The effect of the e-bike was greater for female than for male cyclists, the more so the longer our test users had access to the bike. We found no age differences in the effect of the e-bike.

Our results were mixed for our final hypothesis; namely, that e-bikes will have a greater effect on commute travel than on leisure time travel. The e-bike-related change in absolute distance cycled is biggest for non-commute travel. However, when looking at cycling as share of total commute or non-commute distance travelled, the effect is greatest for commute travel. Weekly cycling activity for transport increased more than cycling for exercise.

It is hard to tell from this whether the e-bike's main societal contribution is in reducing the amount of motorized travel or in a more active lifestyle among the sedentary – most likely both. However, we would argue that since the e-bike has a substantial effect on cycling as a share of total travel distance, its main purpose is as a means of transport. In other words, its main effect belongs in the transport policy domain rather than in the public health domain.

A feature of this study is that we have a full travel diary for all the participants, i.e. we have records of their use of all transport modes on the day of registration. However, the relatively low number of test persons limits the statistical power of computations

like these, and we have avoided calculating such results for vehicle travel. For simplicity, we have presented calculations of cycling mode share, and change therefrom.

In the study, we used self-reported number of trips and distance travelled as outcome variables. Using self-report data is normal in most travel behaviour research (Stopher, 2009). In the current study, we had a rare chance to validate people's self-report data for cycling against an objective measure, the odometer recordings. Previous validations of general travel behaviour data (mostly car use, but also public transport) have shown that people tend to overestimate both trip duration and distance, especially for shorter and middle-distance trips (Witlox, 2007), even if the correlations between self-reports and objective data are quite high, just as they were in this case. The apparent over-reporting of cycling observed in the current study might have had several causes. First, it is difficult for people to remember everyday travel even after a few days (Petrunoff et al., 2013). Second, the odometer records were divided by the number of days the respondent had access to the bike. This included weekends. It could be that respondents did not include their (lower) bicycle use at weekends when assessing the last 7 days of bicycling. It could also be that some respondents used the e-bike more in the last part of the trial than in the early part. It was only the last week that was considered when respondents spoke about their cycling behaviour. More important than the general validity of self-report data is the question whether the test results were influenced by their use. In other words, whether test group respondents in the after-situation would over-report their cycling activity since they felt they should do so (a halo effect). The qualitative reports they gave indicated that this was not the case. Rather, they spoke enthusiastically about how much they had used the e-bike, and gave detailed accounts of long trips they had taken.

In the current study, we observed a gender effect of the e-bike in that females tended to have a greater increased absolute number of trips cycled. The paired samples ANOVA indicated a reverse gender effect for cycling shares of total travelled distance, suggesting that men to a greater extent than women replace other trips with e-bike trips. However, this was not significant in the linear regression, and we therefore conclude that there is no gender effect for cycling as a share of total trip distance. In other words, it seems that the e-bike, to a greater extent, results in newly generated trips for women than for men.

We found no association between age (either linear or as groups) and the effect of e-bikes on cycling activity. This does not contradict previous studies indicating that the most likely purchasers of e-bikes are older people (Fietsberaad, 2013; Fyhri and Sundfør, 2014). Rather it suggests that young people have just as much use of the e-bike as older people, and that their reluctance to buy might be related more to factors such as cost than to issues such as image.

Our findings must be interpreted with some caution. Although the T0 sample size is large, the subsequent T1 and T2 samples are considerably smaller. Our test users number 66 persons, and their characteristics with respect to bicycle use prior to the intervention differed from the control group. Nevertheless, after controlling for this, the estimates obtained appear robust and statistically significant. Participants were

randomly assigned to the test and control groups in the study, and there were no baseline differences between the two groups in cycling activity (randomization was successful). Thus, the manifest differences between the groups are most likely a result of differences in *motivation,* which again results in a certain self-selection. We can see that at all stages of participant contact there is a drop in cycling activity, indicating that those who actually picked up an e-bike were slightly more inclined to cycle at baseline than those who merely stated an interest. Furthermore, those who were willing to respond to all three questionnaires were inclined to cycle more than those who responded to only one or two.

The people who were recruited were not real e-bike owners. Hence, our research has the strength and benefit that it tests the effect of the e-bike controlling for any differences resulting from self-selection, with the limitations mentioned above. Even though this approach has its obvious advantages, being an experimental design, it suffers from limitations regarding its ecological validity: we cannot be sure that the e-bike would have the same effect on people who actually purchase an e-bike, after having gone through a careful decision process about its benefits weighed against its (considerable) costs. However, the most likely outcome of this lacking ecological validity is that we have under-estimated rather than over-estimated the effects of the e-bike. It is quite likely that individuals who run through the decision process about transport needs and come to the conclusion that an e-bike can fulfil their needs to a large enough degree to justify its costs will have a larger latent transport demand than individuals who have not come to that conclusion.

Our inclusion of trial length as a variable has shown that the longer the participants had access to the e-bike the more they used it. Hence, the potential novelty element involved in starting to use an e-bike is less than the learning effect of finding trip purposes for which to use it, and to adjust everyday travel patterns in order to further exploit it, as has been suggested previously (Dill and Rose, 2012).

Still, a limitation of the current study is that most of the participants had the bike for just two weeks, and that only a few had it for four weeks or more. A longer trial period would have allowed us to reach this conclusion with more assurance. Future research should study purchasers of e-bikes in the same controlled manner, thus giving the opportunity to study the effect of the e-bike "in the market", i.e. among those who have made the decision to acquire one and in order to better study long-term effects. Our results are based on a relatively small sample of 66 test persons and approximately 160 controls. The sample size does not allow for strong conclusions or examination of complex relationships. The study is being done in Norway where the e-bike market is expected to take off in the near future (Tronstad et al., 2013). Caution is the by-word when transferring these results to other (market, climate) contexts, but they do stand out as fairly robust, statistically significant and overall in line with existing research and expectations.

5 Conclusions

Compared to motorized transport the bicycle offers many benefits, but still many governments struggle to increase its use. The e-bike promises increased cycling. It

solves many of the reasons people give for not cycling (distance, hills, physically strenuous) and offers many of the same benefits as the car (range, flexibility, rush-hour speed).

The aim of this paper was to investigate several hypotheses about the effect of e-bikes on bicycle use, and to explore the presence of any learning effect. Based on a real-life controlled experiment with 66 participants, the following conclusions stand out:

E-bikes increase the amount of cycling expressed as both number of trips and as distance cycled. Our e-bike test users increased their bicycling substantially and significantly more than did the control group. This applies to commuting as well as all other trip purposes including exercise.

E-bikes have a greater effect on female than on male cyclists. Measured by number of trips, cycling increased considerably among female test users and significantly more than that of their male counterparts. However, the analysis identified no gender effect on bicycling *mileage share* of all transport. This supports the existing literature (e.g. Krizek et al., 2005), which holds that females travel shorter and use the bike for other purposes than men, and importantly that women commute less by bicycle than men do.

E-bikes have similar effects in all age groups. While e-bikes tend to be more popular with older age groups, in particular where the e-bike market is in its infancy, we recorded no difference in effect of the e-bike intervention between age groups in our test group. The e-bike offers advantages to cyclists of all age categories.

E-bikes affect commute travel as well as leisure time travel. The effect of the e-bike intervention is largest for non-commute travels. However, the effect on bicycle share of total commuting mileage differs less. It is clear that even a small increase in e-bike commuting gives a relatively large increase in bicycle mileage.

The learning effect is strong. It was expected that the hype effect of using an e-bike for the first time would be considerable, i.e. that the bikes would be used extensively at the beginning of the trial period. Feedback from test users confirms this. However, the analysis suggests that there is a clear learning effect as well. The longer the test period, the more the bicycle was in use on the last day of the trial. Test e-bike users appeared to pick up new and more ways and purposes for using the e-bike as the trial period proceeded. This finding corresponds well with that of Shao et al. (2012), whose interviewees stated they expected to use their e-bikes more in the future. We conclude that while there is clearly a novelty effect, the learning effect, too, is substantial.

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References

Baker, L., 2009. How to Get More Bicyclists on the Road: To Boost Urban Cycling, Figure out What Women Want. *Scientific American*.

Dave, S., 2010. *Life Cycle Assessment of Transportation Options for Commuters*. Massachusetts Institute of Technology (MIT), Boston.

Dill, J., Rose, G., 2012. Electric Bikes and Transportation Policy Insights from Early Adopters. *Transportation Research Record*(2314), 1-6.

Donaghy, K.P., 2011. Models of travel demand with endogenous preference change and heterogeneous agents. *J Geogr Syst* 13(1), 17-30.

Emond, C.R., Tang, W., Handy, S.L., 2009. Explaining gender difference in bicycling behavior. *Transportation Research Record* 01/2009(2125), 16-25.

Eriksson, L., Garvill, J., Nordlund, A.M., 2008. Interrupting habitual car use: The importance of car habit strength and moral motivation for personal car use reduction. *Transport Res F-Traf* 11(1), 10-23.

European Comission, 2011. Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system.

Fietsberaad, 2013. Feiten over de elektrische fiets, *Fietsberaadpublicatie*, Utrecht.

Fyhri, A., Sundfør, H.B., 2014. Ebikes -who wants to buy them, and what effect do they have? Institute of Transport Economics, Oslo.

Garrard, J., Rose, G., Lo, S.K., 2008. Promoting transportation cycling for women: the role of bicycle infrastructure. *Prev Med* 46(1), 55-59.

Jones, P., Sloman, L., 2010. Encouraging behavioural change through marketing and management: what can be achieved?, *10th International Conference on Travel Behaviour Research*, Lucerne.

Krizek, K.J., Johnson, P.J., Tilahun, N., 2005. Gender Differences in Bicycling Behavior and Facility Preferences, 35 ed. Transportation Research Board, pp. pp 31-40.

Lodden, U.B., 2002. The potential for increasing cycling in Norwegian cities and towns. Institute of Transport Economics, Oslo.

Ministry of Transport and Communications, 2012. Nasjonal transportplan 2014-2023 (National transport plan 2014-2023, Oslo, Norway.

OECD/ITF, 2013. Cycling, Health and Safety.

Petrunoff, N.A., Xu, H., Rissel, C., Wen, L.M., van der Ploeg, H.P., 2013. Measuring workplace travel behaviour: validity and reliability of survey questions. *Journal of environmental and public health* 2013, 423035.

Pucher, J., Buehler, R., 2008a. Cycling for Everyone Lessons from Europe. *Transportation Research Record*(2074), 58-65.

Pucher, J., Buehler, R., 2008b. Making cycling irresistible: Lessons from the Netherlands, Denmark and Germany. *Transport Reviews* 28(4), 495-528.

Shao, Z., Gordon, E., Xing, Y., Wang, Y., Handy, S., Sperling, D., 2012. Can Electric 2-Wheelers Play a Substantial Role in Reducing CO2 Emissions? University of California, Davis, p. 21p.

Stopher, P.R., 2009. The Travel Survey Toolkit: Where to From Here? *Transport Survey Methods: Keeping up with a Changing World*, 15-46.

Taniguchi, A., Fujii, S., 2007. Promoting public transport using marketing techniques in mobility management and verifying their quantitative effects. *Transportation* 34(1), 37-49.

Tronstad, H., Fyhri, A., Kvisle, H.H., Bjerck, J.E., Skollerud, K., 2013. «Gi sykkelen et dytt» - Internasjonale erfaringer med elsykler og eventuelle

barrierer for suksess i Norge, *TØI working paper*. Instute of Transport Economics, Oslo.

Verplanken, B., Aarts, H., van Knippenberg, A., Moonen, A., 1998. Habit versus planned behaviour: A field experiment. *Brit J Soc Psychol* 37, 111-128.

Vågane, L., Brechan, I., Hjorthol, R., 2011. National Travel Survey 2009 - key report. Transportøkonomisk institutt, Oslo, p. 101.

Wiederkehr, P., 2012. Ecodriving, e-Mobility with "Green" Electricity from Renewable Energy in Austria, *PEP Workshop, Green, Health-friendly, Sustainable Mobility in Urban Central Asia*, Almaty, Kazakhstan.

Wu, C.X., Yao, L., Zhang, K., 2012. The red-light running behavior of electric bike riders and cyclists at urban intersections in China: An observational study. *Accident Analysis and Prevention* 49, 186-192.