SUPERCYKELSTIER

ELECTRIC BICYCLE REPORT

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MOBYCON | REGION OF COPENHAGEN

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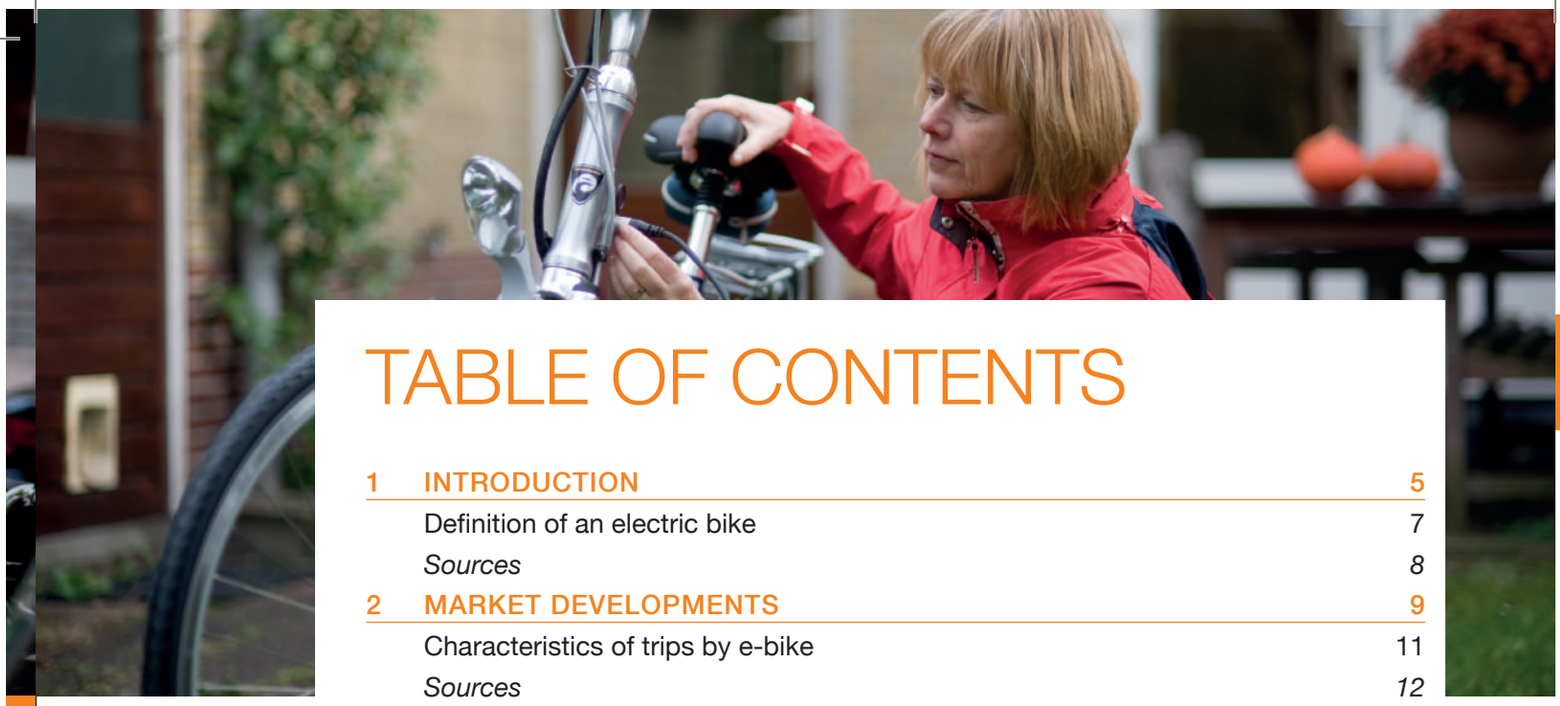

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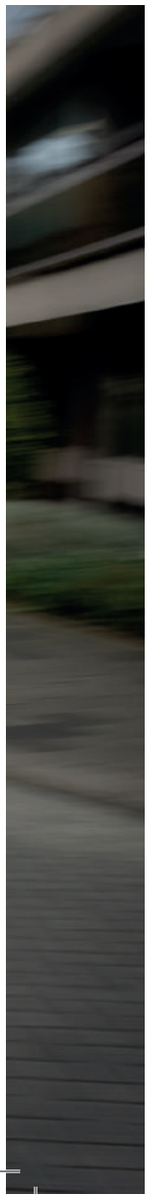
1 INTRODUCTION

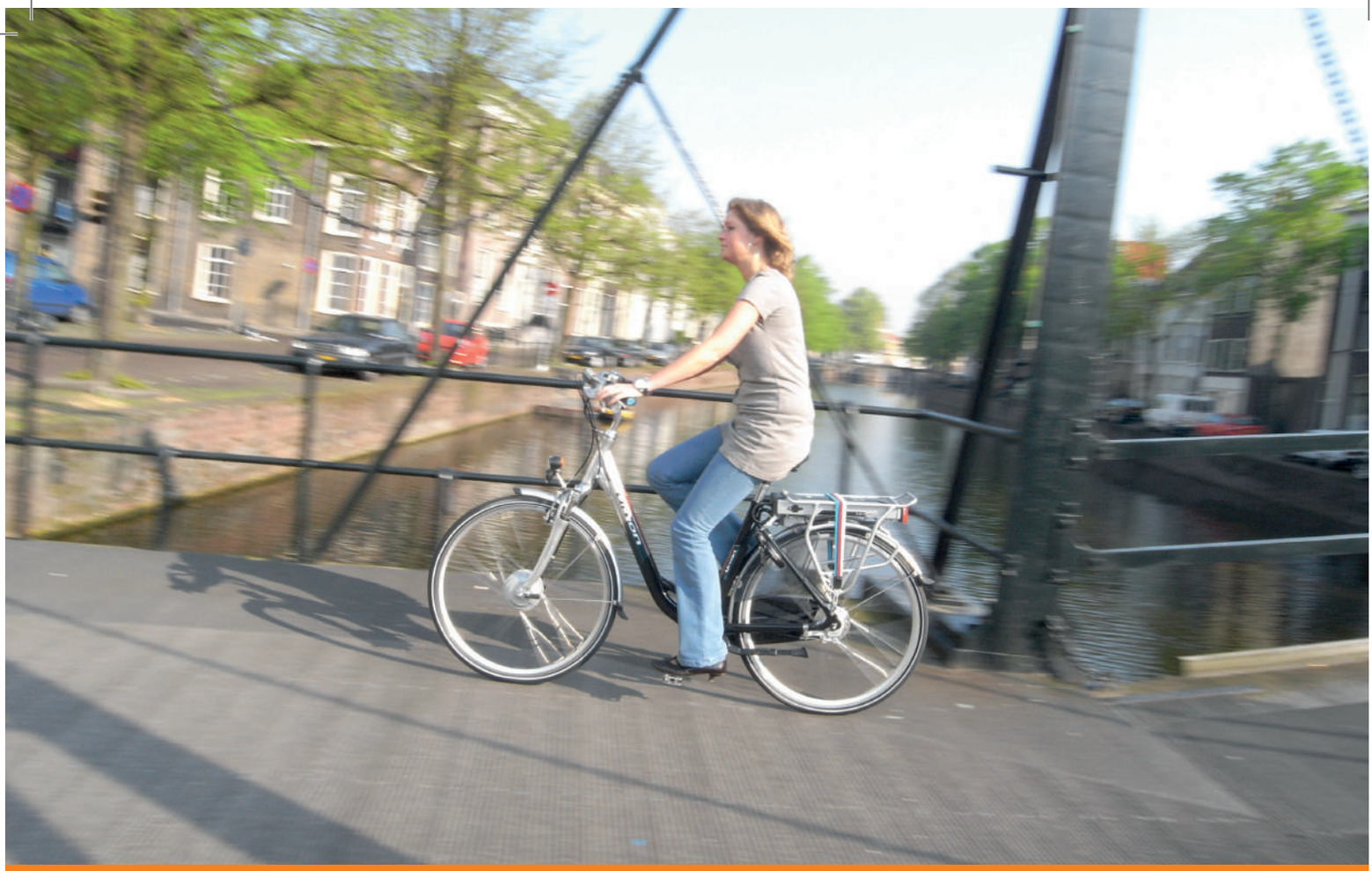


The electric bike has a huge potential in transferring commuters from cars to bikes, on longer distances, and can thus, combined with the Cycle Super Highways, make it even more attractive for commuters to travel on a bicycle.

22 municipalities and the Capital Region of Copenhagen have been working together, since 2009, to create a network of Cycle Super Highways. The network is targeting commuters who travel more than 5km to and from job or studies. The electric bike gives you a helping hand in the head wind, and up the hill, and it is a cheap and quick means of transportation, as well as a good alternative to the car or taking the bus.

In Denmark the electric bicycle is slowly gaining a growing interest in the population, but has not yet established itself as a means of transportation, in the same way as the car, bus, train or conventional bikes. But *what are the implications if more people start to ride the electric bicycle, and how does this compare to riding a conventional bicycle?*

There is very little knowledge in Denmark about the implications of the use of the e-bike. Do electric bikes pose any new safety challenges, which are not present with conventional bicycles? Riding a bicycle improves individual health, and decreases societal health costs. How does the electric bicycle contribute to health compared with a conventional bike or when compared to driving a car? What are the environmental implications of riding a bike that is powered by electricity? Riding an electric bicycle allows a greater number of cyclists to travel at higher speeds. Does this create new needs and challenges for the way we design infrastructure? This report tries to answer these questions based on European knowledge, and especially from the Netherlands.




ITALIA
MESS

DEFINITION OF AN ELECTRIC BIKE

An electric bike (e-bike) is a bike with an electric motor that supports pedalling. A battery powers the motor. With the same amount of energy from the cyclist the e-bike has a higher speed compared to a conventional bicycle. In other words, the cyclist on the e-bike needs to give less energy to reach the same speed as the cyclist on a conventional bicycle.

Riding an e-bike is often described as 'cycling with continuous wind in your back'.

However, due to the weight of the battery that powers the electric motor, e-bikes are on average 9kg heavier than conventional bikes.
Since 2002, in the European Union (EU), it is forbidden that the output of an electric motor is more then 250 W, and the maximum speed that will be supported by the electric motor of the e-bike is 25 km/h. This excludes e-bikes from meeting the type-approval of two or three-wheel motor vehicles, hence categorizing them as conventional bicycles. It also means that you do not need a driver's license, a license plate, insurance or a helmet. However, you do need to fulfil the requirements of a conventional bike, e.g. lighting and reflection, should the member state law specifies it. In 2009, a European standard was adopted to provide design, assembly, engine power management systems and electrical circuits requirements and specifications for the e-bikes. This standard was the result of a high European demand from manufacturers and e-bike advocates. In the Netherlands, e-bikes that do not require pedalling are defined as mopeds.
It is not only the conventional city bike that has been transformed into different e-bike versions. Other types of e-bikes include e-cargo-bikes and electric tricycles.

Despite the fact that clarifications have been brought on the status of e-bikes, future improvements in the legislation are expected considering the rapid development and diversification of e-bikes.

Some ideas have emerged, notably suggesting a limit in maximum power-assisted speed – that would be proportional to the pedal power applied – rather than a drive system power limit. This would match the situation of a regular bicycle, where speed is proportional to muscle power, and allow people going uphill without difficulty anymore.

ADVANTAGES OF AN ELECTRIC BIKE

An electric bicycle has many of the same advantages that conventional bicycles have, when compared to cars. It is healthier, better for the environment and needs less space than a car does.

Due to the 'continuous wind in the back' the e-bike is seen as a vehicle seriously competing with car trips on distances up to 15 or 20 kilometre.

Due to the electric motor, the advantages of the e-bike can be smaller than what they would be for a conventional bicycle. But when the e-bike substitutes to cars due to its competitiveness, the overall effect is bigger.

DISADVANTAGES

- An e-bike is heavier than a conventional bike
- Elderly are less skilled in traffic
- Relative high numbers of accidents

SOURCES

Amendments by the European Parliament to the Commission proposal Regulation (EU) No .../2012 of the European Parliament and the Council on the approval and market surveillance of two- or three-wheel vehicles and quadricycles [2012] A7-0445/148/rev

Directive 2002/24/EC of the European Parliament and of the Council of 18 March 2002 relating to the type-approval of two pr three-wheel motor vehicles and repealing Council Directive 92/61/EEC [2002] OJ L124/1

European Committee for Standardization (2011). *Cycles - Electrically power assisted cycles - EPAC Bicycles.* EN 15194:2009+A1:2011

Go Pedelec Project Consortium (2012, July 17). *Go Pedelec handbook.*

2 MARKET DEVELOPMENTS

EUROPE

The e-bike is becoming increasingly popular in Europe. Although it is difficult to track the exact number of e-bikes sold every year due to a variety of classifications (hence the need for legislating on e-bikes as different vehicles than conventional bikes), one can say the sales are growing at a constant rate: about 200,000 extra e-bikes are sold every year. Figure 2.1 below shows the distribution of e-bikes sold in 2012 across the EU (Croatia not included back then). One can see that

in absolute numbers most e-bikes are sold in Germany (45% of sold units) and in the Netherlands (21% of sold units). Nevertheless, these numbers need to be adjusted to population size; when taking the countries' population into account, it is clear that the Netherlands – followed by Denmark and Austria – are the countries with the most e-bikes sold per inhabitant,

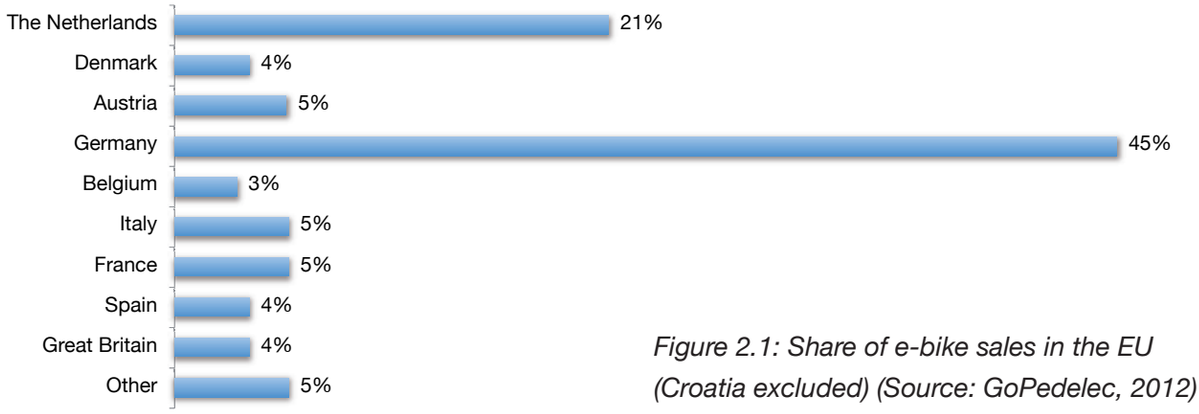


Figure 2.1: Share of e-bike sales in the EU (Croatia excluded) (Source: GoPedelec, 2012)

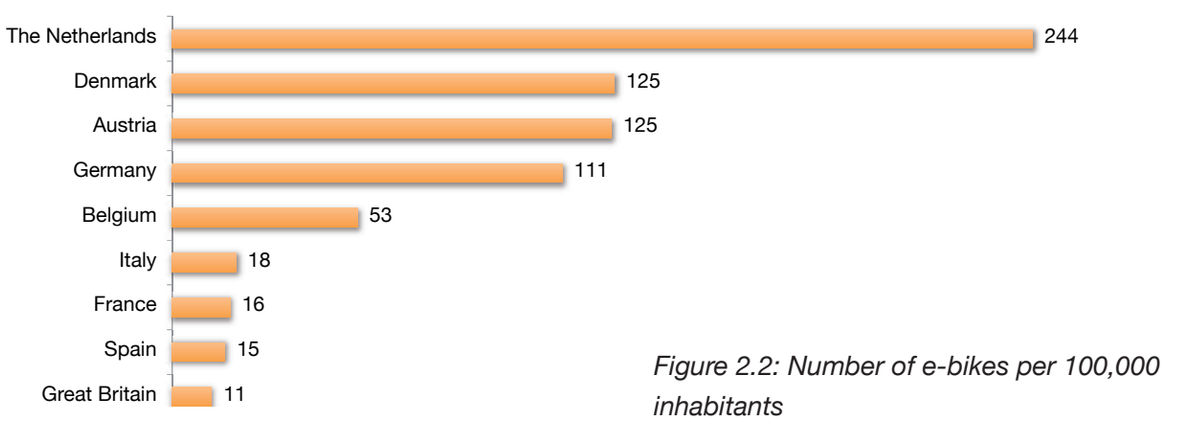


Figure 2.2: Number of e-bikes per 100,000 inhabitants

with 244 e-bikes per 100,000 people (Figure 2.2). As a matter of fact the Netherlands and Denmark have very high-quality cycling networks and hence can easily attract new types of bicycles. Note however that up to now e-bikes remain a marginal mode of transportation, with very few units per inhabitants.

SALES OF E-BIKES IN THE NETHERLANDS

There are about 19 million bikes on Dutch roads and about 1 million (6%) are e-bikes.

Before 2004 hardly any e-bikes were sold in the Netherlands. In 2004 the share of e-bikes in all bicycles sold was 2%. In 2007 this share was 6% and it kept on rising steadily up to 20% in 2011.

It is expected this figure will grow fast in the upcoming years, due to the high percentage of e-bikes being sold compared to that of conventional bikes and the prediction of an even further increase of e-bike sales in the coming years.

The e-bike is most popular amongst the elderly, and within this group, it is especially appreciated amongst women.

A strong increase in the use of the bicycle amongst this group has a strong relation with the rise of the popularity of the e-bike, research shows. Compared to the year 2000, women aged 60+ in 2009 cycled 19% more kilometres. We also know that 24% of bicycle kilometres of elderly women are done by e-bike, while this level was around 0% in 2000. The level of bicycle ownership in this group has increased as well, up to 10% of women over 60 (Table 2.3).

Currently e-bikes are also getting more popular amongst younger groups. More affordable prices and better batteries play their part, as well as a growing acceptance of e-bikes and smart marketing by the bicycle industry that now offers more models and puts its focus on commuters.

	Men	Women	Weighted average
< 46 y/o	1%	1%	1%
46-60 y/o	7%	13%	10%
> 60 y/o	10%	10%	10%
Weighted average	4%	6%	5%

Table 2.3: Percentage of people owning an e-bike in the Netherlands in 2012 with respect to age and gender (Source: Fietsberaad, 2013)

WHY BUYING AN E-BIKE?

Elderly buy an e-bike mainly because it is easier to ride and gives more comfort (longer distances are possible, a "push at the back with the wind"). *People under the age of 65 use their bike for commuting and they do appreciate the higher speeds for longer distances* when compared to conventional bikes. In the Netherlands, the reasons why people decide to purchase an e-bike are: (1) the pedal assistance that an e-bike provides to make biking an accessible alternative to move around (44% of e-bike owners surveyed in 2013); (2) the support of the pedal assistance when strong adverse wind conditions (42%); and (3) the possibility of reaching further destinations, hence the increase in accessibility to jobs, leisure, and services (35%). A point worth noting is that people under the age of 55, on top of agreeing with the above-mentioned reasons, appreciate the higher speeds that can be reached more easily with an e-bike. They represent 11% of the people aged 12-54, when only 2% of the people over 55 care about this aspect of the e-bike.

CHARACTERISTICS OF TRIPS BY E-BIKE

LENGTH OF TRIPS

The average distance cycled on a conventional bicycle in the Netherlands is 18 km per week. On the e-bike the average distance cycled increases to 31,3 km per week. This is partly due to an increase in kilometres per user, but is probably also caused by the fact that e-bikes are bought by people who want to cycle further in the first place. Almost half of the users of the e-bike are 'heavy users'; they use the e-bike more than four times a week. Women are overrepresented in this category of heavy users. Light users form 20% of the users of e-bikes; they use their e-bike only once a week or less. They tend to be a bit older than the average user of the e-bike, have a high-income level and live in a city.

Finally, note that *irrespective of age, more kilometers are cycled with an e-bike than with a conventional bike.* For men the trip distance on e-bikes even increases with the age (Table 2.4).

Table 2.4: Weekly distance traveled with respect to age, gender and bicycle type in the Netherlands (Source: Fietsberaad 2013)

	MEN		WOMEN		WEIGHTED AVERAGE	
	e-bike	Conventional bike	e-bike	Conventional bike	e-bike	Conventional bike
< 46 y/o	33.3	22.2	29.6	19.3	31.2	20.7
46-60 y/o	34.2	18.8	29.1	15.6	30.9	17.3
> 60 y/o	35.4	15.3	28.3	14.5	31.6	15
Weighted average	34.9	19.6	28.7	16.9	31.3	18.2

SPEED

In contradiction to what one may expect, the speed difference between cyclists has not increased due to the rise in the numbers of e-bikes. Indeed, Dutch research shows that the speed difference has been reduced due to the use of the e-bike. *Elderly keep up with the speed of other adult cyclists!* That could be confusing for other road users since they may not expect an elderly person on a bike to cycle with the same speed as them. *It is however expected that when e-bikes get more popular amongst younger groups, the speed difference between conventional bikes and e-bikes will increase.*

TRIP PURPOSES

THE MAIN PURPOSE OF TRIPS ON E-BIKES IN THE NETHERLANDS IS RECREATIONAL.

Other motives are shopping and visiting people. This focus on private trips, and not trips to school or work, reflects the high proportion of elderly using the e-bike.

In the Netherlands, people have stated that they use their e-bike for leisure (77%), shopping and running errands (68%) and visiting family and friends (47%). Some disparities exist across age groups. For instance, people over 65 show a strong tendency to use the e-bike for recreation purposes (89%) and for shopping (68%), where commuters are less inclined to use it for these same purposes (64% and 60% of the people in this category stated these preferences). Without surprise, *the number one reason why commuters who own an e-bike ride theirs is to get to work more easily, and faster* (64% of the respondents agreed).

SOURCES

COLIBI – COLIPED. (2013). European Bicycle Market – 2013 edition: Industry & market profile (2012 statistics).

Fietsberaad. (2013, May). *Feiten over de elektrische fiets.* Publication 24, version 1.

Go Pedelec Project Consortium (2012, July 17). *Go Pedelec handbook.*

Hendriksen I., Engbers L., Schrijver J., van Gijlwijk R., Weltevreden J., and Wilting J. (2008). *Elektrisch Fietsen Marktonderzoek en verkenning toekomstmogelijkheden.* TNO KvL/B&G/2008.067

Kruijer H., den Hertog P., Klein Wolt K., Pannerman M., and Sprik E. (2013, March). *Fietsongevallen in Nederland.* VeiligheidNL.

3 HEALTH FOR E-BIKERS COMPARED TO REGULAR BIKERS

RECOMMENDED PHYSICAL ACTIVITY

The World Health Organization (WHO) recommends that adults aged 18 to 64 engage in at least 20min of moderate-intensity physical activity per day, or 10min of vigorous-intensity physical activity per day. Each activity period should last at least 10min. Finally, extending the duration of daily activity can provide additional health benefits, and muscle strengthening will take place if major muscle groups are in use at least twice a week.

TARGET GROUP 1: COMMUTERS

Interestingly enough, the WHO notes “inactive people should start with small amounts of physical activity and gradually increase duration, frequency and intensity over time.” This makes the case of the electric bicycle an excellent option for this roup of people.

The electric bicycle can indeed be an opportunity as a soft transition vehicle to get car-driving commuters to ride a conventional bicycle. This is especially the case for employees who find that they live too far from work to get on a bicycle, or that cycling is too slow to get to work, despite the fact that they would like to exercise daily. *According to the study by TNO it can be expected that the electric bicycle could be responsible for an increase of about 10% in the number of bike commuters.*

This could be of great interest for the employers since healthier employees would lead to less health care expenses, more productivity, and an overall better mood and environment at work.

TARGET GROUP 2: ELDERS

Since the population is ageing in Europe, it is of prime importance to treat the case of 65+ people with care, in order to improve their health. It has indeed been shown that people over 65 do not comply with the WHO recommended level of activity. The electric bicycle can thus be a great means of keeping elders healthy.

Research has indeed shown that people over 65 are interested in the assistance that the electric bicycle offers. This allows them getting back on a bike to reach the places they used to go to – and even new ones! – or gives them a chance to experience cycling in a comfortable way for those who have never biked in their life.

The electric bicycle can help exercising and burning a great amount of calories in a soft manner through its assistance.

TARGET GROUP 3: PEOPLE SUFFERING FROM OBESITY

It has been shown that riding a bicycle regularly lowers chance of premature death, reduces the risk of chronic diseases, enhances physical fitness, and prevents excess weight. Little by little, this can ensure a new habit for people suffering from excess weight, and therefore help them getting fitter. The idea is that the use of an electric bicycle can be very encouraging since it brings greater accessibility and mobility for people having difficulties to actively go from place to place. Data on whether or how this works in practise is not available.
In the Netherlands, it has been shown that the electric bicycle helps burning 4.7kcal/min – where the conventional bicycle helps burning between 5.9 and 7kcal/min[1]. If one cycles 30min a day and 150 days a year, this means that they can expect to burn 21,150kcal a year. Note however that people with excess weight tend to burn more calories per minute since it requires extra effort to move a greater mass for a given speed.

[1] *By knowing the weight of a bike and a human body, as well as the watts required to power an e-bike to reach a certain speed and maintain it, one can calculate the number of calories required for a trip.*

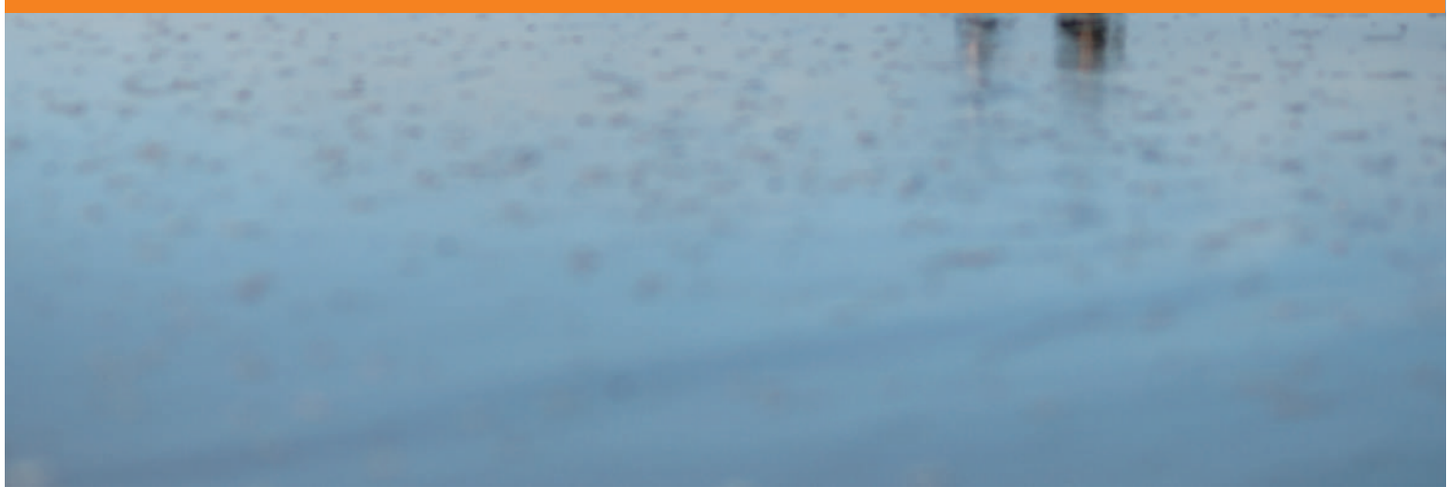
SOURCES

Go Pedelec Project Consortium (2012, July 17). *Go Pedelec handbook.*

Hendriksen I., Engbers L., Schrijver J., van Gijlwijk R., Weltevreden J., and Wilting J. (2008). *Elektrisch Fietsen Marktonderzoek en verkenning toekomstmogelijkheden.* TNO KvL/B&G/2008.067

World Health Organization. (2011). *Global Recommendations on Physical Activity for Health – 18-64 years old.* Last retrieved January 2014, from World Health Organization: http://www.who.int/dietphysicalactivity/physical-activity-recommendations-18-64years.pdf

4 ENVIRONMENTAL ISSUES



MOBILITY EFFECTS

When there is a growth in the use of e-bikes some positive effects on the environment can arise. Because of the electric support, cyclists can ride faster and further with the same amount of personal effort. Also, it is easier to overcome barriers, such as bridges and tunnels. Especially for commuters these factors are very relevant.

Research in the Netherlands found that people who have an e-bike ride 22% more kilometres per week. This is because the cyclists go further and they ride their e-bike more often compared to their pattern with a conventional bicycle.

In the same research the average commuting distance rose from 6.3 to 9.8 kilometres for people who use the e-bike. And there is a substantial substitution from other modes to the e-bike. *34% of the trips on the e-bike were formerly done on a conventional bicycle* and this is mainly the case for recreational routes of elderly. This can be due to the fact that elders have replaced their conventional bicycles by e-bikes for other trip purposes than recreational cycling (i.e. groceries, visiting friends, etc.), and therefore abandoned the habit or the will to use a conventional bicycle for recreational cycling. Another reason could be that e-biking requires less effort and elders can thus bike for longer distances for recreational purposes. Also, it is reported that elders may keep up with cycling up to a higher age, thus creating cycling trips. *18% of the trips were previously done by car,* and primarily done by elders. Another *2.5% of trips are a substitution from a moped to the e-bike* (Table 4.1). Several studies indicate that trips by e-bike do not, up to now, have a high impact on public transport. It is not yet known why this is the case.

Table 4.1: Substitution of the e-bike to other modes of transportation (Source: Hendriksen et al., 2008)

	TOTAL (%)	COMMUTERS (%)	65+ Y/O (%)
Conventional bike	34.3	33.3	43.3
Car	18.3	15.9	19.1
Bus	2.4	5.8	1.2
Walking	2.1	0	1.2
Moped (max. 25km/h)	1.5	0.8	0
Moped (max. 45km/h)	1	3	0
Tram, metro	0.6	1.8	0
Taxi	0.5	0	0.2
Motorcycle	0.2	0.8	0
Train	0.1	0.5	0
Other	1.2	0.8	0
No substitution	37.8	37.4	35.1
Total	100	100	100

ENERGY CONSUMPTION

The electric pedal assistance of an e-bike requires an *energy input for the charging of the battery.* Over the course of a year, it is expected that an average battery needs 270 kWh of electric input in order to power the pedal assistance. If the battery is to be charged via solar energy, this translates to a photovoltaic surface of 2.7m^2.

EMISSIONS

Despite its need for energy consumption, there is a *high potential to reduce emissions through the use of the e-bike as a substitution of car trips.* As the e-bike is an attractive mode of transport on relatively short distances these are often times trips within the build-up area. Here emissions are most harmful and if the trips were done by car they would be done with a cold engine, when emissions are higher.

There is an effect on CO_2 emissions when the number of car trips reduces. The Dutch study in 2008 calculated that with a wide spread use of the e-bike in the Netherlands as a whole about 110 to 280 kilotons of CO_2 emissions could be avoided, which is 0.3 to 0.7% of the yearly emissions in traffic. The assumption for this estimation of the maximum possible effect in the future, is that the ownership of e-bikes in the Netherlands in the future is as high as regular bicycle ownership in the Netherlands in 2008. The emissions that play a role on the local level are e.g. emissions that are harmful when inhaled, such as particulate matter PM_{10} (less than 10 micrometre in diameter) and $PM_{2.5}$ (less than 2.5 micrometre).

EXAMPLE

If a city or region were to implement a pilot project with 1,000 electric bicycles with the aim to attract commuters (hence one round-trip a day), and assuming:

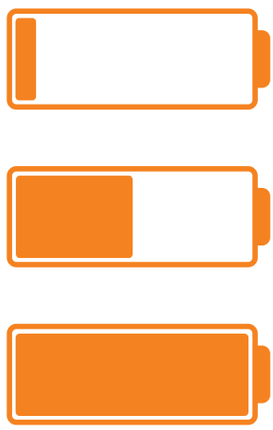
- The average trip distance from home to work is 7.5km;
- 18% of e-bike trips substitute car trips (hence 180 cars);
- 1% of e-bike trips replace moped trips (hence 10 mopeds);
- The car and moped fleet is equally divided from 1997 through 2005; and
- The share of gasoline and diesel car engines is 50/50,

we can estimate that the carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NO), and PM10 emissions over 2850km will be reduced by 7.4kg, 1.6kg, 1.5kg and 0.11kg respectively.

Note that these figures do not take the battery charging emissions, nor their disposal impact on the environment. Ideally the energy source for charging would come from renewable sources such as solar panels.

BATTERIES

There exist four main types of batteries: lead-acid (Pb-acid), nickel-cadmium (NiCd), nickel-metal hydride (NiMH), sodium nickel-chloride (NaNiCl) and lithium-ion (Li-ion). Research has shown that the first three types are less energy efficient – both in terms of production/assembly and usage –, heavier, and presents high difficulties when it comes to disposal (lead and cadmium are extremely toxic materials). Although sodium nickel-chloride batteries are the most energy-efficient, they are slightly heavier than lithium-ion batteries, and require more processing for a safe disposal at the product's end of life. This is why *the European Union is encouraging the use of lithium-ion batteries while strongly restricting the use of lead-acid and nickel-cadmium batteries.*



LIVEABILITY

Other positive effects of the use of the e-bike, as a substitution for shorter trips with the car or the conventional moped and scooter can be seen in the field of liveability. To mention a few: *noise reduction, liveliness on the streets (people on bikes instead of in cars) and social safety.*

SOURCES

European Commission. (2013). *Batteries.* Last retrieved January 2014, from European Commission: http://ec.europa.eu/environment/waste/batteries/

Matheys J., Timmermans J.-M., van Autenboer W., van Mierlo J., Maggetto G., Meyer S., De Groof A., Hecq W., and van den Bossche P. (2006). *Comparison of the Environmental impact of 5 Electric Vehicle Battery technologies using LCA.* In proceeding of: 13th CIRP International Conference on Life Cycle Engineering 2006, Leuven, Belgium.

Mobycon. (2008). Rotterdam gaat elektrisch fietsen. Fietsberaad.

Hendriksen I., Engbers L., Schrijver J., van Gijlwijk R., Weltevreden J., and Wilting J. (2008). *Elektrisch Fietsen Marktonderzoek en verkenning toekomstmogelijkheden.* TNO KvL/B&G/2008.067

Loijen J. (2011, October). Elektrische fiest in Haaglanden – Onderzoek naar het gebruik van de elektrische fiets in Haaglanden. Stadsgewest Haaglanden.

5 SAFETY FOR E-BIKES COMPARED TO REGULAR BIKES

With the spectacular rise of the use of e-bikes in the Netherlands over the last years and the rise of the number of seriously injured cyclists, *the question rose whether the e-bike is a less safe way to cycle, compared to a bicycle without the support of a battery.* Research is currently being carried out to get a better insight in cycling behaviour when riding on the e-bike and on the nature, range, underlying causes and consequences of accidents with electric bicycles. With these new insights a program to prevent accidents with e-bikes can be developed, in the case of e-bikes being less safe. Research methods include focus groups, questionnaires and an experimental field study with cameras, instrumented bicycles and sensors on the cyclist to study the reaction on several situations that have to be dealt with in traffic.

SPEED AND MENTAL WORKLOAD

The field experiment with middle aged (mean age 38) and older (mean age 70) cyclists revealed that both age groups rode *significantly faster on an e-bike than on a conventional bike*. On straight sections the difference was greatest whereas in curves the difference was small. But in all situations and on both types of bicycles *the older cyclists, when compared to the middle-aged cyclists, rode slower*. The speed of the elderly cyclists on e-bikes turned out to be the same as middle-aged cyclists on conventional bicycles. As for the mental workload, it was found that it was higher in complex situations compared to simple ones, but it did not make a difference whether the test person rode a conventional bike or an e-bike. The researchers stated that *it looks like cyclists of all ages, on both types of bicycles, slow down their speeds in complex traffic situations*. Further research will have to prove this. The difference in speed on cycle tracks seems to be less nowadays, compared to some years ago. Thanks to the e-bike more people can keep up with the average cycling speed. This is good for cycling safety, as there is *less overtaking and conflicts amongst cyclists*.

One thing may be *more unsafe, which is the expectancy of other road users seeing elderly people with a certain sitting position on a bicycle that looks like a conventional city bike, not expecting them to keep up with the average speed.* In the future the difference may increase, when more younger and fitter people also start to use the e-bike, for their commute of 10 to 20km for example.

NUMBER OF ACCIDENTS WITH CONVENTIONAL BIKES COMPARED TO E-BIKES

61,400 p/year

9,100 p/year

The estimated number of cycling accidents with *conventional bicycles* in the Netherlands is 61,400 people per year. They end up at the emergency and first aid units of hospitals. The *majority of these victims are male (57%) and the average age is 38 years*.
The estimated number of people in the Netherlands who had an accident with *an e-bike* and ended up at the emergency and first aid unit of a hospital is 9,100 per year (15% of all cycling accidents). The *majority of the group of e-bike victims is female (70%) and for this group the average age is 66 years*.

CAUSES: SINGLE SIDED ACCIDENTS AND INVOLVEMENT OF OTHER ROAD USERS

Most of the accidents with conventional bicycles are single sided accidents, caused by the cyclist falling off the bike. Younger victims (12–24 years) are more often involved in accidents with other road users, compared to older age groups, or in accidents where they hit an object. Younger victims also state that the accident happened while cycling or stunting on the bike. Victims aged 65+ often fall from the bicycle *when getting on or off their bicycle*. Furthermore, half of the victims state that their behaviour on the conventional bicycle played a role in the cause of the accident. Amongst younger victims (12-24 years) in about half the cases the behaviour of other road users played a role, whereas amongst the elderly cyclists (65 and older) this was only the case in about a quarter of the cases. A problem with the technical state of the bicycle mainly played a role in the younger age group.

Just like accidents with conventional bicycles, most accidents with e-bikes occur because the rider falls off the bicycle. When corrected for age differences, the causes and types of accidents of people on e-bikes and people on conventional bikes are comparable.

Still, in 17% of the cases the rider of the e-bike states that the fact that he/she rode an e-bike played a role in the accident. This is especially true for the 12-54 years age group. They mention that the weight of the e-bike and the speed played a role.

The age group of 12 to 54 years seems to ride the e-bike for health reasons more often and fall from the bike in a stationary position more often.

PLACE AND TIME

Most accidents with conventional bicycles occur on separated cycle tracks or in streets, especially at straight tracks. Accidents take place in the curves too, and in half of the cases these accidents are related to the state of the road. Most accidents occur during the week between 9am and 4pm, although younger victims have most accidents at night. Overall alcohol played a role in 7% of the cases, mainly amongst victims up to 49 years. These accidents mainly occur in the weekend and at night.

CONSEQUENCES

Most of the victims who rode a conventional bicycle were wounded after falling; younger people relatively often by hitting an object, elderly people relatively often by getting on and off the bicycle. The age of the victim and the type of injury are related: the older the victim is, the more fractures and the younger the victim, the more superficial injuries and distortion.

Elderly victims are hospitalized more often after a bicycle accident and they expect the injury to have lasting effects more often compared to younger victims. Lastly, more elderly victims expect that they will not be able to ride their bicycle any more after having had the accident.

Up to now, it looks like the consequences of the accidents with the e-bike overall are comparable with the consequences of accidents with conventional bicycles.

Especially since it is still unclear whether self selection plays a role in the purchase of an e-bike: the group buying an e-bike may differ from the rest of the cyclists which makes it hard to say whether the accident happened because the rider was on an e-bike or because the group is at higher risk anyway.

SOURCES

Fietsberaad. (2013, May). *Feiten over de elektrische fiets.* Publication 24, version 1.

Kruijer H., den Hertog P., Klein Wolt K., Pannerman M., and Sprik E. (2013, March). *Fietsongevallen in Nederland.* VeiligheidNL.

Twisk D.A.M., Boele M.J., Vlakveld W.P., Christoph M., Sikkema R., Remij R., and Schwab A.L. (2013). Preliminary results from a field experiment on e-bike safety: speed choice and mental workload for middle-aged and elderly cyclists. In proceeding of: International Cycling Safety Conference 2013, 20-21 November 2013, Helmond, The Netherlands.

6 NEW CHALLENGES FOR INFRASTRUCTURE

Policy makers in a number of European countries have high expectations from the e-bike as it can be a serious alternative to cars for short trips. At the same time the outstanding rise of the use of e-bikes creates new challenges for existing and new bicycle infrastructure. Recently several research projects have been set up in the Netherlands, aiming at *understanding whether the existing guidelines for cycling infrastructure need to be adapted and if a different approach towards bicycle parking facilities is needed*.

THE BICYCLE NETWORK AND CYCLE TRACKS

SUSTAINABLE SAFETY

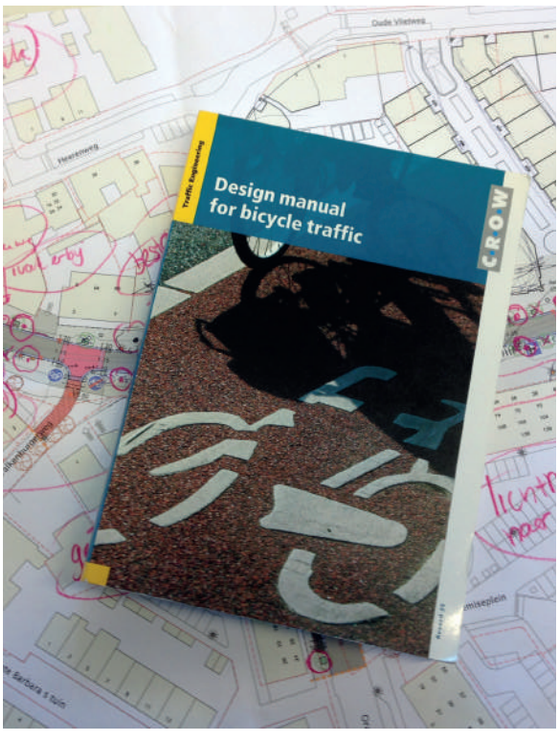
A short overview of the Dutch vision on safe infrastructure is at its place. *Denmark and the Netherlands are both countries that rank high in traffic safety figures, while ranking high in bicycle usage.* In the Netherlands the road safety policy is identified as good practice. 'Sustainable Safety' is the leading vision behind this policy. The five principles of Sustainable Safety are:

- The functionality of roads
- The homogeneity of mass and/or speed and direction
- Physical and social forgivingness
- Recognition and predictability of roads and behaviour, and
- Self awareness (the ability of road users to predict their own competences correctly).

Figure 6.1 shows the steps that translate this vision into actual design for cycling facilities on the road. In the design phase, the five main requirements (coherence, directness, safety, attractiveness and comfort) of the national bicycle design manual (also known as CROW manual) play a crucial role.

Figure 6.1:
From the Sustainable Safety vision to design of cycling facilities.

The current research questions aim to understand the five requirements from the perspective of the e-bike in comparison to the conventional bicycle. An important aspect is that a large proportion of e-bike users are elderly, who are seen as vulnerable road users.



BICYCLE NETWORK AND ROUTES

There is a relation between the usage of an e-bike and urbanization: e-bike users cycle a longer distance when the degree of urbanization decreases. Two factors explain this trend. First, people use an e-bike more often for recreational cycle trips compared to the usage of conventional bicycles. Even in the case of conventional bikes, people in less urban areas make more recreational cycling kilometres. Second, the commuting distance between home and work and between home and shops in less urban areas is larger. The e-bike is an attractive alternative for the car, while the conventional bike is not an option anymore.

With this in mind there might be new challenges in the regional bicycle network: certain areas or routes that were previously not interesting enough for a large group of users, could now become more popular. One of the consequences is that municipalities need to collaborate more in order to make sure that the network in the outskirts of the municipality match that of the neighbouring municipalities.

CYCLING HIGHWAYS

The first ‘cycling highway’ in the Netherlands opened in 2005. It is a 7.5 km high quality cycle route between the cities of Breda and Etten-Leur in the province of Noord-Brabant.

The aim to start building cycling highways is to help avoiding traffic congestion by stimulating car drivers who live up to 15km from their workplace to switch to the use of the bicycle. Hence this development started before the high rise of e-bike usage.

Since the e-bike is an interesting alternative to conventional cycling, especially since commuters have to travel 5 – 15 kilometres, these developments create a positive synergy in the promotion of cycling. In 2013, there were 25 cycling highways in the Netherlands and there were plans for 675 extra kilometres.

The ambition to tempt a cyclist to cycle a greater distance creates needs for different infrastructure designs. The average speed of cyclists using the e-bike is expected to get higher: less stops at intersections and a minimum of the inconvenience when passing cars. The user experience and how network, route choices and design may influence this experience is becoming more important. The expectancy is that there is a growing overlap between recreational routes and regional routes for commuters. An attractive, smooth and quieter route is also appreciated. In general one can say that the bicycle infrastructure on cycling highways should be wider.

In the ideal situation the width of a cycle highway is about 7 meter (3 meter per direction, including a median strip in between). In practice, 4 meter with a median strip is the minimum.

A FORGIVING CYCLE PATH

As we already saw in the chapter on safety, a lot of the accidents with e-bikes and with conventional bikes in the Netherlands are single sided accidents and a substantial part of the victims are elderly. Cyclists fall off the bicycle e.g. when getting on or off the bicycle, when they bump into bollards, when the road is slippery or when there is a height difference between the road and the shoulder that was not well visible. The development of the concept of a ‘forgiving cycle

path' derives from the third principle of Sustainable Safety: 'physical and social forgivingness'.

The design of this cycle path is self-explaining, corrects when mistakes are being made and reduces the seriousness of accidents.

Research on the concept is currently being carried out, but a few examples of measures in the infrastructure have already been presented. Like white lines or profiled road markings clearly marking the edges of the separated cycle path, led lights in the median of the separated cycle track and profiled road markings when approaching a bollard. Finally, *evacuation times at traffic signals may be adapted to serve the elderly cyclists who increasingly use e-bikes and by that continue to cycle up to a higher age.*

WAYFINDING

As said before, there might be a growing overlap between recreational and commuting routes in the Netherlands. As it is easier to cycle longer distances with an e-bike, wayfinding becomes more important for both recreational cyclists and new (e-)cycling commuters. *On-street way finding, combined with information available on the Internet are good services that support the new users of e-bikes.* There are different web-based tools and smart-phone apps available. Some interesting tools to mention are the cycling route planner from the Danish Cycling Federation (http://cyclistic.dk/en/) and the international route planner NAVIKI (www.naviki.org).

BICYCLE PARKING AND CHARGING POINTS

NUMBER OF STOLEN E-BIKES IN THE NETHERLANDS IN 2013

With the rise of the number of e-bikes being sold, the number of stolen e-bikes in the Netherlands is also rising. One insurance company – the market leader in the Netherlands for selling (e-)bicycle insurances – recently published an article in which they estimate that 25,000 e-bike were stolen in 2013, with an estimated value of 45 million euros. With this in mind, it is clear that *safe, accessible and convenient bicycle parking facilities at strategic locations, such as city centres, neighbourhood shopping areas and workplaces, are important.*

BICYCLE PARKING

Just like users of cargo-bikes and bikes with child seats, the *e-bike users have their own wishes*. E-bike users are afraid that the e-bike will be damaged when parked in the open space so they do not want to park the bike at every location. The characteristics of the e-bike that cause this are:

- the e-bike has a higher steer with more and vulnerable cables and computer;
- the e-bike is heavier and the division of the weight is different compared to the conventional bicycle, which causes fear for a bending of the wheel;
- the e-bike has a broader frame and;
- the e-bike is more expensive.

Also, elderly state that it is problematic to lift the e-bike into bicycle parking facilities.

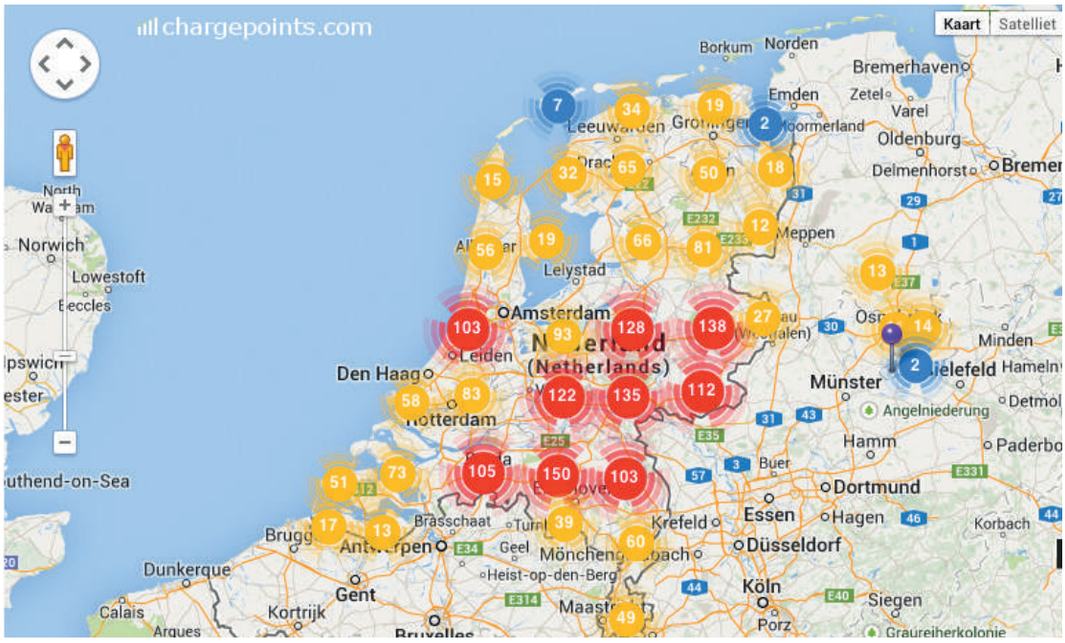
In many cases the best solution for users is to have a bounded, but open area to park the e-bike on the kickstand. The only Dutch parking system that meets the wishes of the majority of the Dutch e-bike users is the typical ‘nietje’.

CHARGING POINTS

Several Dutch municipalities are nowadays installing *charging points in their public municipal bicycle parking facilities*. Users of e-bikes appreciate this, but in fact *an accessible power socket and a shelf on which to put the adapter fulfil the actual needs*. Especially since the action radius of the battery has increased to over 60km. At the

same time, a simple charging point can overcome the psychological barrier as it reduces e-cyclists risk of an empty battery. For destinations that are further away and at places where people spend more time, like working locations and recreational destinations, charging points are valued positively.

Entrepreneurs in recreation and tourism and the bicycle industry have already placed thousands of charging points at cafés, restaurants and shops. If we take this into account, together with the fact that more bicycles have batteries that can be removed from the bike, charged anywhere and the achievements of batteries are growing, the question is how necessary it is to place charging points as a municipality.



SOURCES

Algemeen Dagblad. (2013, December 3). *Dieven azen op elektrische fietsen.* Last retrieved January 2014, from Algemeen Dagblad: http://www.ad.nl/ad/nl/1100/Consument/article/detail/3555517/2013/12/03/Dieven-azen-op-elektrische-fietsen.dhtml

Centrum Fietsdiefstal. (2013, December 3). *Diefstal e-bikes flink toegenomen.* Last retrieved January 2014, from Centrum Fietsdiefstal: http://www.centrumfietsdiefstal.nl/nieuws/2013/031213_diefstal-e-bikes-flink-toegenomen#.Us_qZeB92xG

Fietsberaad. (2013, May). *Feiten over de elektrische fiets.* Publication 24, version 1.

De Graaf P. (1999). *Nieuwe 'fietssnelweg' krijgt automaten met plaksetjes.* Last retrieved January 2014, from Volkskrant: http://www.volkskrant.nl/vk/nl/2664/Nieuws/archief/article/detail/533133/1999/11/02/Nieuwe-fietssnelweg-krijgt-automaten-met-plaksetjes.dhtml

Hendrik R. (2013). *Zo realiseer je een snelle fietsroute.* In Fietsverkeer 33, pp.14-19, Fiestberaad.

Morsink P., de Waard D., and Bakker K. (2013). Het Vergevingsgezinde Fietspad – Op weg naar Duurzaam Veilige fietsinfrastructuur. Nationaal Verkeerskunde Congres.

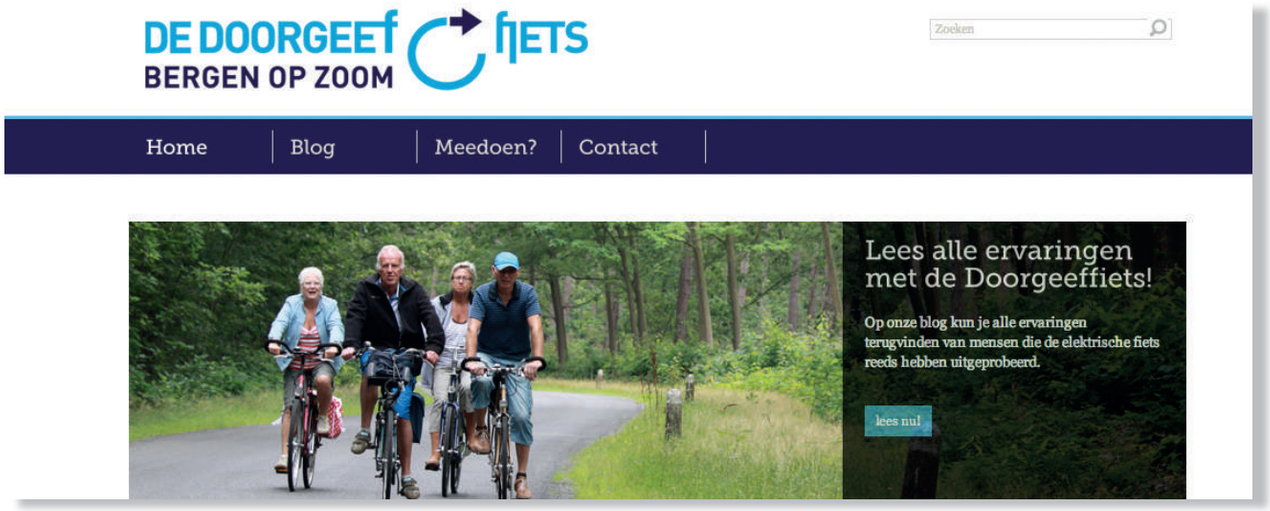
7 PROMOTION OF E-BIKES IN THE NETHERLAND

The bicycle industry and several public authorities have reasons to promote the e-bike for certain target groups in the Netherlands. The industry needs the promotion to sell their products.

Public authorities see that the e-bike can potentially replace car trips up to 15 or 20km, which could mean less need for investments in car infrastructure.

THE BICYCLE INDUSTRY

The first groups that were targeted by the bicycle industry for the sales of e-bikes were the *elderly* and *physically handicapped people*. For the physically handicapped the extra support from the battery of the e-bike is a welcome support, and it seems that it was widely accepted from the beginning of the development of the e-bike that this vehicle was suitable for this target group. This was not immediately the case for many of the elderly that ride e-bikes nowadays. A lot of effort has been put into making the image of the e-bike more attractive. An important step in this process was the fact that from 2007 onwards the e-bike was seen as equal to a regular bicycle, not needing a special insurance. Until then an e-bike was treated as a moped and its insurance was hence set to a similar cost to that of a moped. In the meantime, *the battery of the e-bike became more and more 'hidden' in the frame of the bicycle, and it therefore became less clear whether a person was riding a conventional bicycle or an e-bike. From that moment onwards the sales of e-bikes started to grow at an ever-increasing rate.*



The next target group is *commuters*. Over the last years the idea that commuters can substitute e-bike trips to car trips has become more accepted. The industry co-operated with non-profit organizations and the public sector. In many cases they provided test *bicycles for pilot projects and promotion campaigns*. In their advertisements, websites and catalogues, the commuter group is well represented.

The newest target group for the bicycle industry is *youngsters*. In some (rural and suburban) areas the scooter and moped are popular amongst 16-18 year old youngsters. *The idea is that the e-bike and e-scooter can replace the scooters and mopeds these youngsters ride*. Moreover, for the youngsters that are younger, some assistance from a battery in windy situations would be much appreciated. For their trips to secondary school (age 12+) some youngsters make trips up to 15, and even 20km one way, daily. It is not clear yet what specific activities the industry will undertake to reach out to this target group.

PUBLIC AUTHORITIES

Since 2008 /2009 there is a growing number of public authorities that facilitate employers to promote the e-bike amongst employees. In general the reasoning behind these mobility management measures is that *it is more cost efficient, environmentally friendly and healthy to stimulate car users to start using the e-bike for their commute of 5 to 15km, compared to the investments that would be needed if roads had to be widened to overcome and avoid traffic congestion.* This fits within the current Dutch approach to first fully use the infrastructure that is already available, before building new roads.

One of the first of these mobility management e-bike projects started up in the city of Rotterdam and was called “E-fiets: proberen is overtuigen” - “E-bike: trying is convincing” (later turned into the name “Electric Fantastic”). The aim of the project was to disseminate the use of the e-bike amongst employees of large companies in Rotterdam. Employees of the nine participating companies could hire an e-bike for free for an entire week (from Monday to Monday) so that they can test it for their commute. The employees had to fill in a questionnaire before and after the trial period, which made it possible to get more insight about the potential of the e-bike for commuting trips.

In August 2009, 279 people had tried the e-bike, of whom 125 filled in the evaluation form. A few of the results of this pilot project are presented here below:

- The usual modal split of the “e-bikers” was: 37% by car; 29% by bike; 22% by public transport; and 12% use a mix of modes.
- On average the e-bike has been evaluated very well with an average grade of over 4 out of 5.
- 49% of the users thought that the e-bike is worth its price and 39% would be willing to pay for it.
- 74% of the participants considered the e-bike a suitable transport mode for their commuting trip.
- People’s main reason to not consider the e-bike a suitable means of transportation for their commute were: the commuting distance being too high (38%); the preference for the conventional bicycle (22%); the technical limitations of the bicycle (15%) such as a low battery range and insufficient pedal assistance.
- The average commuting radius increased from 9.2km to 13km.
- 60% of the car users thought that the e-bike could fulfill their commuting trip. Their typical commute distance is 9 to 19km.
- 36% of the participants stated that they were planning to buy an e-bike in the near future. If they were not going to buy one it was mainly because of the high price.

In 2011 the City of Heerlen (in the ‘hilly’ south of the Netherlands), together with local bicycle shops, *financially supported its 60+ year-old inhabitants who wanted to buy an e-bike*. A group of selected bicycle shopkeepers gave a € 200 reduction on the price of an e-bike and the municipality doubled this reduction with another € 200. They had a budget of € 100,000. *Reasons for this measure were CO_2 reduction and, as a health prevention measure, supporting elderly who want to keep on cycling or want to pick up cycling again.*

Finally, a recent study looked at the cost effectiveness of two similar e-bike commuting campaigns by weighing the costs of the campaign against different types of effects. The conclusion was that *these measures are very cost effective:*

The costs of the campaigns are 5 to 8 eurocents per kilometer, compared to structural subsidy on public transport being 22 eurocents per kilometer.

The costs of the campaigns per car kilometer are 6 to 10 eurocents. But it is not sure to what extend the reduction of car trips takes place during peak hours and at peak locations.

The costs of the campaigns per kilogram of CO_2 emission saved are 38 to 62 eurocents. This is high compared to the price in the international trade in emissions.

The cost of the campaign per car parking spot is € 540 to € 760. The cost effectiveness for this type of effect depends on how much pressure there is on car parking spots in the area where car trips are replaced by e-bike trips. In case of a shortage of parking space, this type of effect alone is enough to make the whole campaign cost-effective. The yearly cost of a car parking spot is around € 950 per car commuter, with a range between € 108 up to € 2,503.

SOURCES

Fietsberaad. (2013, May). *Feiten over de elektrische fiets.* Publication 24, version 1.

Gemeente Heerlen. (2011, February). *Subsidie elektrische fiets.* Last retrieved January 2014, from Gemeente Heerlen: http://www.heerlen.nl/Pub/Home/Home-Nieuwsberichten/Home-Nieuwsberichten-Stadsplanning/nieuwsberichten-SP-2011/Subsidie-elektrische-fiets.html

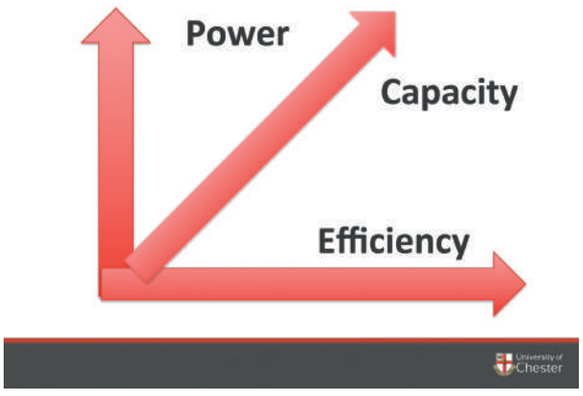
Mingardo G. (2009, December 10). *Electric-Bike as alternative to car use: evidence from a pilot project in Rotterdam.* In proceeding of: POLIS Conference, December 2009, Brussels, Belgium. Last retrieved January 2014, from Polis Network: http://www.polisnetwork.eu/uploads/Modules/PublicDocuments/electric_bike_in_rotterdam.pdf

Rabobank. (2013). *Rabobank in cijfers en trends – Branche-informatie – Tweewielerspeciaalzaken (Automotive).* Last retrieved January 2014, from Rabobank Cijfers en Trends: https://www.rabobankcijfersentrends.nl/index.cfm?action=print.printPdf&id=6dd8fb72-c91e-4aa4-a524-06cc2bf41e20

8 THOUGHTS ON INNOVATIONS IN THE MOBILITY INDUSTRY

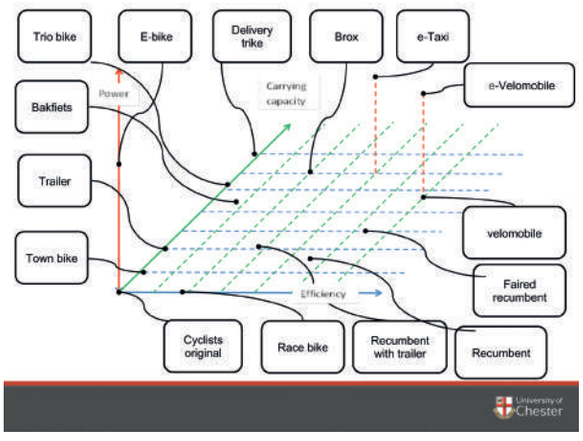
SAFER E-BIKES

The bicycle industry and a group of ten interest groups in the Netherlands are paying close attention to the safety of the e-bike and it's use. They work on several improvements such as a *lower entry level* of the bicycle, a *better image for mirrors* on the e-bike (lessen the taboo), the *reduction of the weight* of the e-bike and *having the weight as low as possible* in order to improve balance and a more subtle support (like up to 18km/hr). Also attention is being paid to the *possibilities of tricycle e-bikes*, which should be more interesting for people with balancing problems.



A BICYCLE, A MOPED OR A CAR?

There is a growing number of vehicles on the market that fit somewhere between a conventional bicycle and a moped or a car. The Beerbike in Amsterdam caused problems in traffic because of its big format and slow speed in the streets; this vehicle is now banned from the streets in Amsterdam. For other vehicles the worries tend to be focussed around the high speed, causing more speed differences, hence more overtaking for which enough width is needed. Again leading to the question what the right guidelines for separated bicycle infrastructure are.



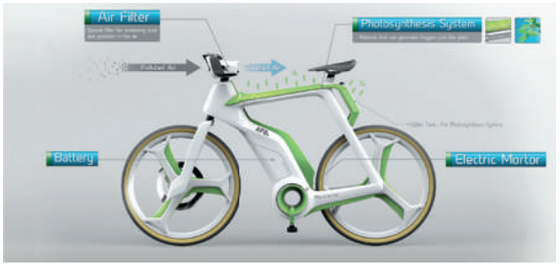
Over time, it seems that the bicycle, originally meant to go from point A to point B in a cheap way, has developed to meet various needs, such as delivery of goods (capacity), speed (efficiency) and comfort (power), as seen in the figures above. One can see that *the latest ideas and developments, such as the e-taxi and the e-velomobile, are aiming at meeting those three human needs: moving people and goods in an comfortable and efficient manner*.

ITS AND ICT IN TRANSPORTATION

In the years to come a growing number of intelligent transport systems (ITS) and information and communication technologies (ICT) developments will take place in the field of traffic, transport and mobility. Nowadays we already see a variety of systems like traffic management systems, route planners, speed adaptation, counters etc. Generally speaking, these applications are developed for motorised traffic. These vehicles increasingly communicate with each other and with the infrastructure, or they use online information, with the aim to make traffic safer and more convenient. The EU project SAFECYCLE researched the possible contribution of ITS to improving safety for cyclists, which included e-cyclists. One of the findings of the project was, that (e-)cyclists (as well as pedestrians) are not a self-evident part of the conversations that increasingly take place between participating vehicles in traffic. *Our cars, trucks and buses become smarter, as well as our infrastructure. But up to now (e-)cyclists, bicycles and pedestrians are not a part of the conversation.*

With the growing use of e-bikes and other smart techniques that can be attached to conventional bicycles, there are more possibilities to start to include the (e-)bicycle in this ITS conversation.

POLLUTION EATING BIKE



Another new concept with e-bikes is the idea to develop an e-bike that is not only cleaner for the environment than a car, but is even used as a machine to clean polluted air. This example from Lightfrog creative studio in Bangkok has a handlebar-mounted air filter and a photosynthesis system that can generating oxygen with its lithium-ion battery, which powers the e-bike, as seen in the picture below. This type of technology could potentially zero the negative effects of charging the battery.

SOURCES

Brownstone S. (2013, December 10). *Purify the air as you ride, with this photosynthesis bike.* Last retrieved January 2014, from Fastcoexist: http://www.fastcoexist.com/3023176/purify-the-air-as-you-ride-with-this-photosynthesis-bike

Diepens J. (2013). *Let's talk about IT – Cycling cities facilitate cyclists and bicycles to join the conversation.* In proceeding of: Velo-city 2013 Conference, 11-14 June 2013, Vienna, Austria.

Markham D. (2013, December 10). *Air-purifying bicycle concept eats pollution, generates oxygen.* Last retrieved January 2014, from Treehugger: http://www.treehugger.com/clean-technology/air-purifylng-bicycle-concept-eats-pollution-generates-oxygen.html

Cox P. (2013). *A diversity of Machines*. In proceeding of: Velo-city 2013 Conference, 11-14 June 2013, Vienna, Austria.

9 RECOMMENDATIONS

In this report we answered a variety of questions around the use of the e-bike compared to the use of a conventional bicycle. Answers in the domain of health prevention, environmental impacts and infrastructural challenges are mainly based on studies from the Netherlands. Over there *it is now obvious that the e-bike is meant to stay and not only for a small group of elderly and disabled people. It is there and will be increasingly popular for a growing number of people who like to ride bicycles*. Batteries get smaller in size, but longer lasting, making the e-bike more attractive. E-bike models can be found in different styles and shapes, suiting a variety of people. All of this means that *we have to rethink our image of what the bicycle is*, what the health and environmental benefits are and what types of infrastructure are needed to facilitate this trend. The good news is that *the e-bike also offers new opportunities*, as seen in the examples from the Netherlands. It is a serious alternative for the car, making it an instrument in mobility management. And it generates extra bike trips, especially amongst elderly for whom it is healthy to stay active.

What would happen if the region of Copenhagen embraced the e-bike? What number of trips up to 20 km by car could potentially be substituted by e-bike trips? And what could be a fast route to reach that result? What partners would be needed; how can the bicycle industry get more involved; what is needed to make an e-bike a serious alternative for longer commute trips in the region? How can the public opinion be influenced positively? We recommend the Region to conduct a *market and feasibility study*, specifically aimed at the region, to answer these questions. And the *development of a strategy* based upon that, *so that the e-bike optimally contributes to the cycling policy goals and ambitions of the Region.*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