Introduction

Chapter 1

1.1. Background

"I had been back in New York for only a week. As is always the case when I arrive after a period of months away, I was tuned to any change in the city's ambient hum. When that bike flew past, I felt a shift in the familiar rhythm of the city as I had known it. I watched the guy as he travelled on the green bike path. He was speeding down the hill, but he wasn't pedaling and showed no sign of exertion. For a moment, the disjunction between effort and velocity confused me (..)."

The above passage is part of the introduction to an article in the New Yorker titled "The e-bike conundrum" (Beller, 2017). In the article, the author describes his thoughts following this strange encounter. As a cyclist, there is something inherently fraudulent, offensive even, about not having to work for your momentum. But after giving in to his curiosity, he tries one out for himself: *"Now and then I could feel the happy bump of electric power. Assisted living was so pleasant!"*

Media reports on the topic of e-bike mobility in recent years have varied from accounts of a "rage" (Wallack, 2017) and "revolution" (Laker, 2017) to more critical narratives of the limited appeal of e-bikes (Zwetsloot, 2015) and the perception that they tailor to generations of "do-nothings" (Van der Laan, 2015). Regardless of standpoint or tone, the coverage reflects a broader development visible in many, mostly western societies: electrically-assisted cycling is increasingly popular and makes up for a growing share of overall bicycle sales (CONEBI, 2016; Fishman and Cherry, 2015). This development has also caught the attention of the academic community (Fig. 1.1).

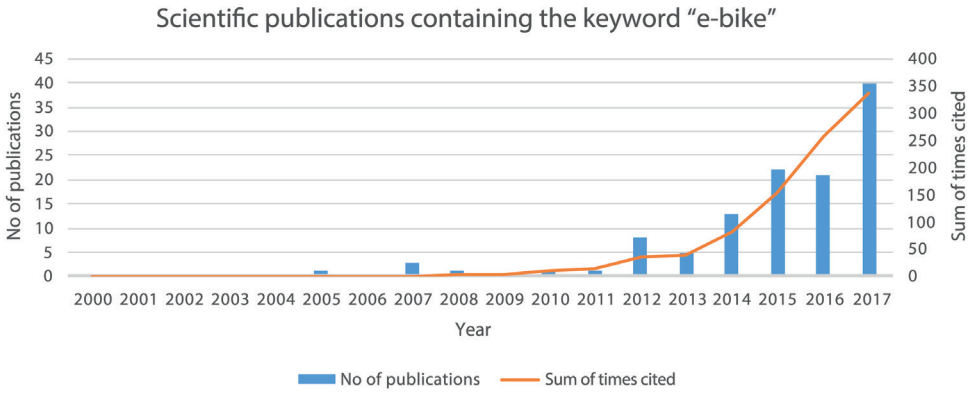

Fig. 1.1 – Scientific publications containing the keyword "e-bike". (Web of Science "all databases" search query = topic:(e-bike), executed on 27-11-2017)

The ascent of e-bike mobility comes at a time where the question of how to de-carbonize transport stands out in political and academic discourses around the world. The benefits of transportation are numerous: it facilitates the movement of people and exchange of

goods, enables engagement in activities, contributes to wellbeing and quality of life, is a catalyst to economic growth, and has to an important extent shaped our societies as we know them today. However, it is also increasingly recognized that the systems of predominantly motorized transport currently in place are unsustainable and have considerable negative impacts on environment, society, public health and the economy (Banister, 2005; Greene and Wegener, 1997; Litman and Burwell, 2006). From an environmental point of view, motorized transportation impacts sustainability through air and water pollution, loss of habitat, hydrologic impacts and depletion of non-renewable resources. Socially, motorized transportation impacts community livability, community interaction and aesthetics, while less-mobile groups are more often disadvantaged and negative impacts tend to be unevenly distributed. From a public health point of view, motorized transport encourages an inactive lifestyle which increases the risk of life-style related diseases like diabetes type 2, obesity, and heart- and coronary disease. Economically, motorized transportation impacts sustainability through the cost of traffic congestion, accidents, building and maintenance of facilities, costs to the user, and again, the depletion of non-renewable energy resources (Litman and Burwell, 2006).

To strive for sustainable transport systems, environmental, social, health and economic considerations must be included in decisions affecting transportation activity (Litman and Burwell, 2006). This requires fundamental changes in the technology, design, operation and financing of transport systems (Greene and Wegener, 1997). Local and national policies can aim to realize changes in transport technology, transport supply and transport demand. In concrete terms, a shift towards more sustainable mobility requires several, simultaneous actions in the physical as well as the social domains: reduce the need to travel, reduce the absolute levels of car use and road freight, promote energy efficient and active modes, reduce noise and vehicle emissions, encourage efficient use of vehicle stock, improve safety for pedestrians and all road users, and improve the attractiveness of cities for residents, workers, shoppers and visitors (Banister, 2008, 2005). Active modes, such as cycling and walking, can contribute to all but the first objective (Cox, 2008). E-bike use performs similar to cycling and walking on environmental indicators (e.g. Dave, 2010; Thaler et al., 2012) and requires moderate intensity physical activity (e.g. Berntsen et al., 2017). Thus, e-bike mobility has a potential role in the realization of sustainable and healthy transport systems.

The ascent of e-biking is part of a wider development in which electric mobility has gained prominence in visions of low carbon transportation futures. In the public debate, electric vehicles are often seen as the best out of the current options to lower the carbon footprint of transport systems, and "e-mobility is presented as the ultimate solution to nearly all transport problems" (Behrendt, 2017; Kollosche, 2014; Schwedes et al., 2013). The electric car is often central to this discourse, and many countries around the world have introduced some form of financial incentive to accelerate the uptake of electric cars. However, the most-used electric mode today is e-cycling. Thus, in the words of Behrendt (2017), it seems that the discourse on electric mobility is heavily biased towards electric cars, whereas e-bikes could be valued more as a transport mode in their own right [..] "The more diverse understanding of e-mobility [..] could

support a shift of strategies and policies towards more active and sustainable as well as less expensive modes of e-mobility than the current focus on electric cars" (p2).

1.2. Aim of the research and chapter overview

The aim of this thesis is to provide insight in the potential of e-bikes as a means to achieve more sustainable and active transportation, by studying actual and potential e-bike use in different populations and in different regions in the Netherlands. In order to do so, the empirical studies focus on mode choice, modal shift and associated changes in travel behavior and experiences of current and potential e-bike users. The remainder of this chapter expands on the relevance of conducting research on e-bike mobility by discussing the need to de-carbonize transport for the environment, and the need to encourage active transport for public health. Then, the current state of e-bike mobility is examined, followed by a reflection on the value of Dutch e-bike mobility research for an international context. Finally, research questions are presented, along with an outline of the thesis.

1.3. Rationale for this research

As described above, the transport systems currently in place around the world have important negative impacts on the environment, society, health and economy. Two courses of action for mitigating these negative impacts have been proposed in both academic and political arenas. On the one hand, transport's reliance on non-renewable energy sources must be decreased. On the other hand, levels of active transport must be encouraged to increase sustainability and promote public health.

Central to realizing sustainable mobility is the need to decarbonize transport. There are two important reasons for this need: concerns over energy security as a result of the dependence on fossil fuels, and concerns over the environmental effect of transport. Cheap natural resources such as oil have permitted relentless growth of transport systems and travel and trade (Banister et al., 2011). As such, transport has become dependent on petroleum products such as gasoline, diesel and jet fuel: global transport depends on oil for 94% of its energy needs, and this is even higher in the EU (96%) and the US (97%) (European Commission, 2011; Schäfer et al., 2009). This has brought into question concerns over oil scarcity, oil price volatility, and energy security. The vulnerability of global fuel supply systems was made clear by oil supply disruptions during the oil crises in the 1970s. And until today, oil and gas security remain concerns of foreign and military policies of importing regions (Banister et al., 2011; Schäfer et al., 2009). Diversification of energy sources through development of alternatives, for instance electric mobility powered by renewable energy sources, is an important strategy to guarantee the functioning of global systems of transport.

Second, energy use in the form of fossil fuels contributes to the majority of transport's environmental impacts. Incomplete combustion of petroleum fuels in internal combustion engines produces a variety of pollutants, and transport (especially road

vehicles, road and maritime freight, and aviation) is a major source of these pollutants (Banister et al., 2011; Greene and Wegener, 1997). Due to its abundance, CO2 is considered the main contributor to the anthropogenic greenhouse effect. According to Banister et al. (2011), decarbonizing the world transport system requires decoupling economic growth from transport and emissions through creative combinations of new transport technologies and a reorganization of the ways in which travel and freight movements are undertaken. An overview of the variety of measures which can be taken that target transport supply and demand can be found in their article.

Another course of action to mitigate the negative impacts of transport systems described above is to increase levels of active transport. Current patterns of transportation affect health in multiple ways: traffic accidents, especially road traffic accidents, are a major cause of death and serious injury; road transport is a major contributor to air pollution, and human exposure to air pollution can have consequences for health including cardiovascular and respiratory diseases; and traffic noise can cause annoyance, sleep loss, communication problems, and learning problems in younger age (WHO, 2005, 1999). Using active transport instead of fossil-fueled motorized transportation indirectly benefits public health by countering these negative health effects. Furthermore, it directly benefits health due to the required physical activity, which induces cardiovascular exercise and among other things has been shown to reduce mortality due to obesity and other diseases related to an inactive lifestyle (see Pucher & Buehler 2010 for an overview). The World Health Organization's charter on Transport, Environment and Health (1999) posits that forms of transport that entail physical activity, such as cycling and walking, separately or in conjunction with public transport, can offer health gains, but have often been overlooked in planning and decision-making

As a mode of transport that is both sustainable and active, cycling has (re-)gained momentum in past years (Agervig Carstensen and Ebert, 2012). Another contributor to this momentum is the diversity of newer, electrically-assisted bicycle types offering new groups of people the opportunity to cycle distances which were previously only accessible for the tough and dedicated cyclist (Agervig Carstensen and Ebert, 2012). E-bikes require lower levels of physical activity than regular cycling, but preliminary evidence suggests that assisted cycling can still satisfy moderate-intensity standards and thus offer health benefits (Gojanovic et al., 2011; Simons et al., 2009; Sperlich et al., 2012). Thus, the e-bike holds potential to unite the benefits of active modes (physical activity, health benefits, enjoyment) and motorized modes (ease of use, range) to function as a viable intermediate alternative which can help move towards more sustainable and active transport systems.

1.4. The case in point: e-bike mobility

The first electric bicycle designs can be traced back to patents obtained around the end of the 19th century (e.g. Bolton, 1895; Libbey, 1897). These designs either never made it into production, or had limited appeal to the masses. In recent decades, however, e-bike sales have grown globally. Especially China has seen a significant uptake of

e-bikes with annual electric bike sales growing from 40.000 in 1998, to 10 million in 2005, to 37 million in 2013 (Wei, 2014; Weinert et al., 2007). This growth consisted of a transition from human-powered bicycle use, bus and gasoline-powered scooter use to e-bike use, and has been attributed to a combination of rising household incomes, decreasing e-bike prices, improvement in e-bike technology and favorable policies. It is important to clarify that the e-bikes sold in China tend to differ from the e-bikes most commonly used in Europe and North America. Chinese e-bikes are mostly "scooter-style electric bicycles". Here, the power is throttle controlled, and the pedals are often included for regulatory purposes and do not provide much function. European and North American e-bikes are more often "bicycle-style electric bicycles", with functional pedals and pedaling assisted by an electronic motor (Fishman and Cherry, 2015).

In Europe, e-bike sales make up for an increasing share of overall bike sales: in the Netherlands and Belgium for instance, around one third of all bikes sold today are electrically assisted (CONEBI, 2016). In the Netherlands, e-bikes were initially popular with older and physically-impaired individuals, for whom the e-bike enabled cycling with greater ease due to the pedal assistance. E-bike use is still the highest among middle-age and older people; nonetheless, they hold growing appeal to increasingly younger populations including students, commuters and parents, who carry children and groceries or travel long distances on a day-to-day basis (KiM, 2016; Peine et al., 2016) (Fig. 1.2).

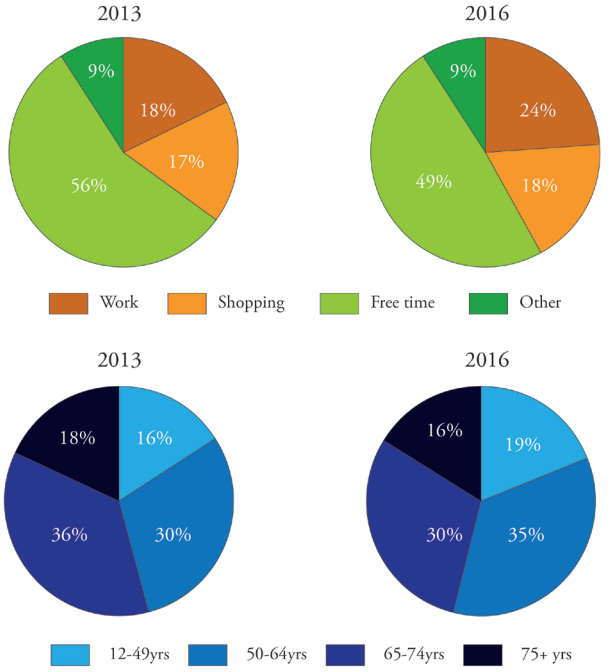

Fig. 1.2 – E-bike kilometers categorized by goal (above) and age category (below) in the Netherlands in 2013 and 2016 (KiM, 2017; edited)

This implies that the adoption of e-bikes has followed an unconventional path. According to Rogers's innovation diffusion theory, innovations spread through adoption by innovators and early adopters, who are defined as 'venturesome cosmopolites' with 'control of substantial resources', and 'role models' with 'high degree of opinion leadership' respectively (Rogers, 2003). These are characteristics which might not commonly be associated with middle-aged and elderly people. The 'inverse' development of e-bike use, with adoption at later stages happening among increasingly younger populations, has been termed the "rejuvenation of e-bikes" (Peine et al., 2016). In their words, "this upsets existing age-related assumptions that run through the diffusion of innovation literature—assumptions that, often in passing, assume older persons to be laggards with low degrees of innovativeness" (p21) (Fig. 1.3).

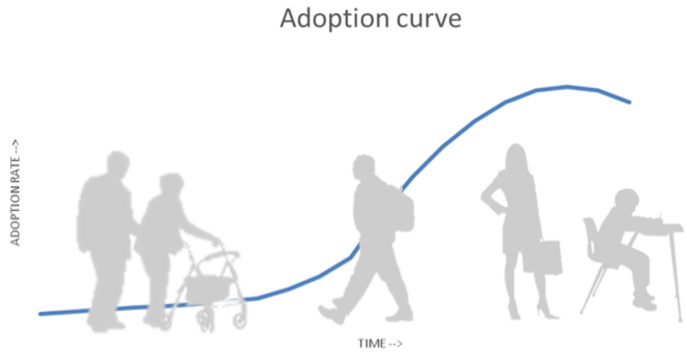

Fig. 1.3 – Rejuvenation of e-bike adopters (image by Peine et al, 2016; reprinted with author permission and with permission of SAGE Publications, Inc.)

The most common e-bike used in the Netherlands is the bicycle-style e-bike, which is legally defined as a bike propelled by user pedaling, with an electronic motor providing assistance up to 25 km/h and a maximum capacity of 250 W. For this type of e-bike, the same regulations count as for regular bikes: no driver's license, insurance and license plate are required. Furthermore, there are no age restrictions, and helmet use is not mandatory (Rijksoverheid, 2017). Also used, although to a far lesser extent, is the speed pedelec (Statistics Netherlands, 2017). It is legally defined as a moped, with an electronic motor providing assistance up to 45 km/h. Different regulations apply to this e-bike, such as a mandatory license plate and helmet use (SWOV, 2017). In this thesis however, use of the term "electrically-assisted bicycle" or "e-bike" refers to the bicycle-style type of e-bike (maximum 25 km/h, 250 W), unless stated otherwise.

1.5. Value of research in the Netherlands for an international context

Due to a long history of "continuous enthusiasm" for the bicycle, the Netherlands has built itself a reputation of being a true "cycling nation" (Agervig Carstensen and Ebert, 2012). Today, the Dutch modal share for cycling is among the highest in the world. As such, it is a fertile market for the introduction of the e-bike: infrastructural and safety barriers that currently form an obstacle to cycling in other countries, have largely been overcome (Fishman and Cherry, 2015). Studying e-bike mobility in a society where cycling is already a common mode of transport has consequences for the generalizability and transferability of findings as a basis for research and policy in other contexts.

In their study on bicycle cultures with a specific focus on The Netherlands and Denmark, Agervig Carstensen and Ebert (2012) identify a "golden age" for cycling in northern Europe (between 1880 – 1950 approximately), followed by a "renaissance" to overcome the decline of cycling. From the end of the 19th century onwards, cycling in the Netherlands evolved from a high class recreational activity to a transport means for the masses. Cycling stood symbol for the emancipation of women and the working class, and strategic alliances between automobile and cycling clubs forged cycling's position in policy and infrastructure planning. Cycling became part of the "national narrative": a way to identify and express membership of the community, with individuality, strength and independency as its virtues. The rise of the car after World War II caused sharp declines in cycling across Europe from 1950 to 1975 (De la Bruhèze and Veraart, 1999). This decline was also experienced in the Netherlands, although to a lesser extent: cycling was widespread and accepted as a convenient mode of transport, and had a strong symbolic power. Thus, the starting point for a revival was different than in other countries, and as a result, the Dutch bicycle mode share is higher today than in other countries. In recent decades, specific bicycle policies have further cemented cycling's status in transport policies. The connotation of urban livability, and a renewed interest in cycling in other countries, makes that Dutch cycling has developed into a national trademark, with capacity for export (Agervig Carstensen and Ebert, 2012).

Interest in policy lessons increases as a result of discontent with existing policies and/or failure to achieve existing policy objectives (Marsden and Stead, 2011). In recent decades, international exchange in knowledge and policies has been eased by processes of globalization and development of communication technologies. With respect to cycling, the "Cycling Embassy of Denmark" and "Dutch Cycling Embassy" are notable examples of organizations that aim to "encourage cycling all over the world by sharing knowhow" (Cycling Embassy of Denmark, 2017), and "act as an intermediary between the demand for [..] cycling expertise and parties that can deliver" (Dutch Cycling Embassy, 2017). A literal example of transfer and implementation of knowledge from one context to another is Transport for London's "Mini-Hollands'" program. As part of this program, money is awarded to London boroughs to create networks of cycle routes, and improve streets and public areas (Transport for London, 2017). Early experimentation with these schemes, however, also brought about resistance: for instance, the efforts to realize a cycle-friendly environment angered local businesses and residents, who felt ill informed

about the project and disadvantaged by traffic calming and car restrictive measures (Perry, 2014). This anecdotal evidence points at a broader issue: although the efforts might be genuine, in the words of Wright, "there is more to "going Dutch" than having a separate cycling lane" (Wright, 2011). Differences in social, political, and infrastructural settings across countries make it difficult to transfer and generalize findings (O'Dolan, 2013). This is equally the case for the findings from this thesis as a basis for research in other contexts.

It is important to state up front that this thesis does not aim to bring forward a policy agenda on e-bike mobility. Rather, there is a need to add to the existing body of knowledge on e-bike mobility to provide a better understanding of the phenomenon. It is on this basis that appropriate policies can be formulated (Winslott Hiselius and Svensson, 2017). E-bike mobility research is a burgeoning topic and yet still in its infancy, and more research is required on the consequences of e-bike use for travel behavior, vehicle use and mode substitution, health, congestion, emissions and safety (Fishman and Cherry, 2015). In countries like the Netherlands and Denmark, e-bike adoption spreads relatively quickly, and of interest here are adoption by new user groups, substitution rates, types of modes substituted, changes in travel behavior, and the extent to which e-bikes can blend-in with and add to existing bicycle mobility. In countries where cycling is less well-established, however, it will be interesting to see whether e-bikes can accelerate the uptake of bicycle mobility, and leapfrog some of the barriers that toughen regular bike use in the first place: longer distances due to lower-density or sprawling urban areas, lower availability of bike infrastructure, or safety challenges related to speed-differences with motorized traffic. The discussion section of the thesis will provide cues for future research and possible implications for policy and practice. By attempting to answer the research questions outlined in the next section, initial contributions to some of these topics can be made, which are relevant beyond the Dutch context.

1.6. Thesis outline and research questions

The core of this thesis consists of four chapters (Chapter 2-5): Chapter 2 sets the research agenda for the empirical studies in the remainder of the thesis. Three potential new e-bike user groups are identified, and theoretical and methodological advances are described that can form a backdrop to studying potential e-bike mobility in these groups. Chapter 3, 4 and 5 aim to empirically assess this potential. Chapter 3 focuses on the motives, travel behavior and experiences of commuters that recently adopted an e-bike for use in work-related trips. Chapter 4 considers e-bike mobility among younger populations by studying a group of students at a moment of travel habit interruption. In Chapter 5, factors are assessed that contribute to current and potential e-bike use in a rural context. The research questions are as follows:

Research question 1 - Which conditions encourage e-bike adoption by different user groups?

To assess which factors enable a modal shift towards e-bike use, insight is needed in the factors and circumstances that can cause individuals to deliberate current travel behaviors and consider adopting an e-bike. In this thesis, current and potential e-bike use is studied among students, commuters and rural residents. These populations are in general highly mobile, and for many of them e-bike adoption might form a healthy, pleasant and environmental friendly alternative to current daily travel mode choice. However, most of them do not use an e-bike for their daily activities. Throughout Chapter 3, 4 and 5, the deliberation of travel habits is studied among those who already made the choice to adopt an e-bike (e-bike commuters in Chapter 3, rural e-bike users in Chapter 5), those who are currently trying out an e-bike for the first time (students participating in an e-bike pilot in Chapter 4), and those without an e-bike, and who are either interested or not interested in e-bikes (rural residents who do not own an e-bike in Chapter 5). Specific attention is given to the role of key events in the life course that may change routine behaviors, and to interventions in the form of financial incentives or pilot projects.

Research question 2 - What are the advantages and limitations of e-bike use for different user groups?

After deliberating current travel behaviors and considering to adopt an e-bike, mode choice factors might come into play that matter for e-bike mobility specifically. Chapter 2 starts out by identifying the potential of e-bikes for commuters, students and rural residents, and reviews the specific advantages and limitations to e-bike use for each group. The empirical studies in Chapter 3, 4 and 5 offer some further insights as to the accuracy of these notions, and outline how e-bike adoption can be influenced by factors such as affordability, mental wellbeing, physical health, e-bike image, safety and sustainability.

Research question 3 - What are the impacts of e-bike use on travel behavior?

Once the choice to adopt an e-bike is made, the properties of the e-bike might impact users' travel behavior. The previous research questions identified specific advantages and disadvantages of e-bike travel over other modes. The empirical findings from mapping and GPS-tracking in Chapters 3 and 4 provide more insight in how the e-bike impacts the travel behavior of different user groups. These impacts might cause it to be the preferred mode of travel in specific situations, or instead avoided under other circumstances. Furthermore, better insights in the impacts of e-bike use on travel behavior might provide an understanding of the ways in which e-bikes can substitute or complement other modes of transport.