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# Exploring the Adoption of E-Bikes by Different User Groups

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Increased e-bike use can potentially support a shift toward more sustainable and active transport systems. This paper outlines the potential of e-bikes for three user groups that have as yet not fully adopted this mode of transportation: commuters, rural residents and students. For each group, some group-specific advantages and limitations are identified that are likely to shape future e-bike mobility. Then, theoretical and methodological advances in transport geography, mobilities studies and environmental psychology are discussed that may form a backdrop for the empirical study of these groups. Based on this analysis, the use of integrative, mixed-methods research approaches is proposed, which consider potential e-bike mobility as the result of individual decision-making and shaped by social and spatial contexts. This approach may provide a base for the development of effective strategies for promoting the adoption of e-bikes among more diverse user groups.

**Keywords: electrically-assisted cycling, active mobility, commuting, rural residents, students, transport geography, mobilities studies, environmental psychology**

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## INTRODUCTION

Private cars have become the dominant mode of passenger transport in developed countries. The unsustainability of this "automobility regime" is widely recognized (Banister, 2005; Steg and Gifford, 2005), and the transition to more sustainable transport systems stands out in political and academic discourses around the world (Schwanen et al., 2011; Geels, 2012). Thus far, an important element of sustainable mobility agendas has been the promotion of alternatives, such as public transportation. However, public transportation options are often unable to match the quality of accessibility provided by private motorized transport in terms of flexibility, reliability, comfort, and ease of use (Beirão and Sarsfield Cabral, 2007). Similarly, the use of active modes such as walking and cycling can be obstructed by the need to bridge longer distances and the physical activity needed to reach activity locations. In car-centered environments, stimulating the use of active modes and expanding the capacity of public transport requires significant investments, innovations, dedication from related actors and willingness of consumers to change mobility routines to bring about a broad and structural transition to low-carbon mobility in the near future (Geels, 2012).

Within this context, pedal-assisted electric bicycles, or e-bikes, which are becoming increasingly popular in many western countries might provide an interesting alternative[1].

[1]In recent decades e-bike sales have grown globally. Especially China has seen a significant uptake of e-bikes (see: Weinert et al., 2007; Wei, 2014). These e-bikes differ from those most commonly used in Europe and North America. Chinese e-bikes are mostly scooter-style electric bicycles: the power is throttle controlled, and pedals are 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). We estimate that the different types of e-bikes have specific consequences for travel behavior and usage patterns. Therefore, we clarify here that the bicycle-style electric bicycle is the focus of this perspective article.

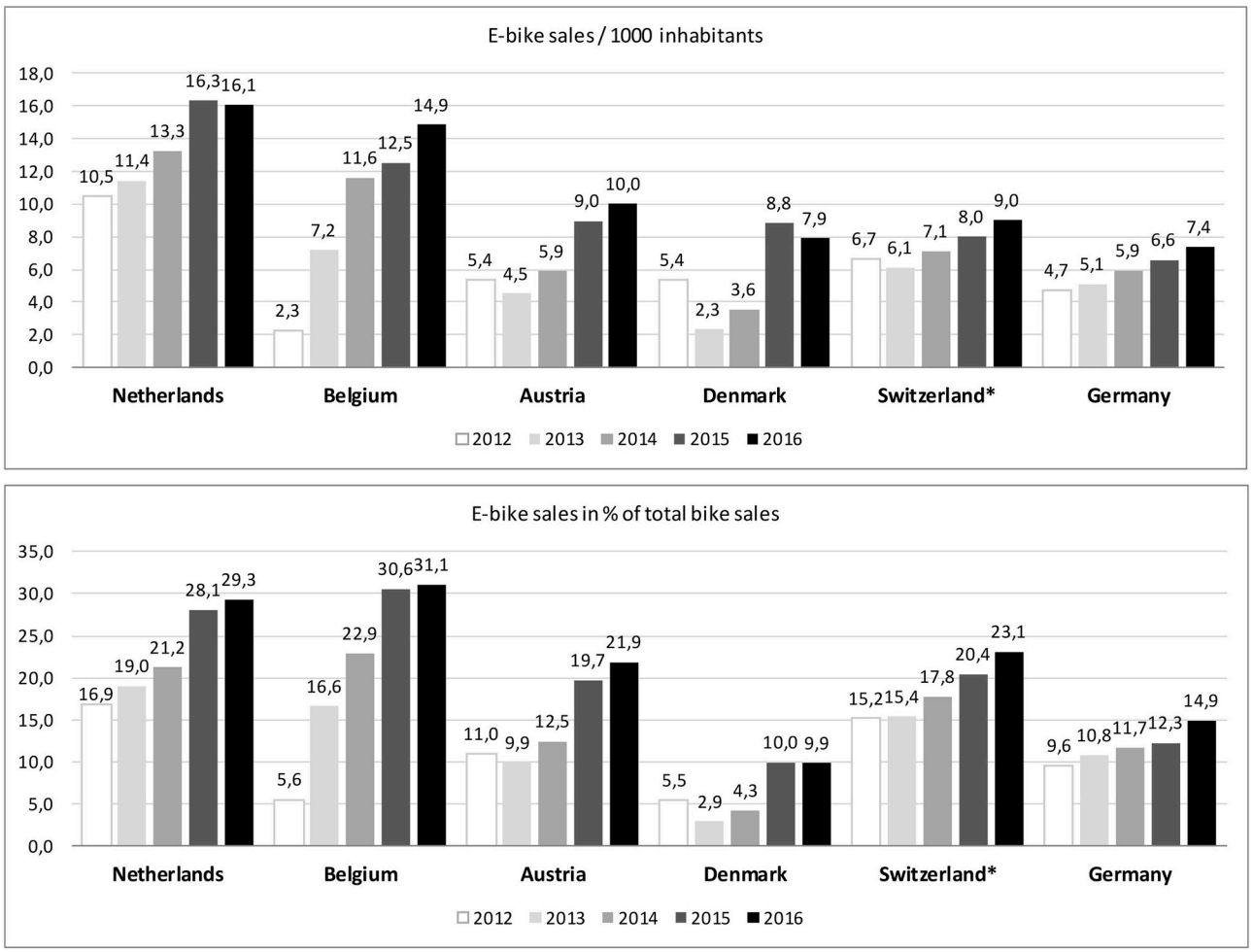


**FIGURE 1 |** Electric pedal-assisted bicycle sales per 1,000 inhabitants (left) and as share of total bike sales (right) in five European countries and Switzerland [data sources: CONEBI (2016); *Vélosuisse (2017); EUROSTAT (2017)].

Today, in countries like the Netherlands and Belgium, e-bikes account up to almost one in three bikes sold (**Figure 1**). E-bikes combine propulsion by user pedaling with assistance through a computer-guided electronic motor. This enables cycling at augmented and constant speeds using reduced physical effort, and covering longer distances in shorter amounts of time. The e-bike thus seems a viable alternative to car-use, especially for medium-range distances that most people would consider too far for cycling.

E-bikes first gained popularity among older and disabled people as an alternative to regular cycling or for leisure. However, in recent years, e-bike use has become more mainstream (Ki, 2016). The extent to which this will continue, and whether e-bikes will substitute motorized transport, will largely depend on the rate of adoption by a broader range of user groups. Therefore, we argue that it is timely for research on e-bikes to pay more attention to the advantages and limitations for e-bike adoption by potential user groups. Better insight in this can ultimately help support a shift toward more sustainable transportation systems.

In this paper, we first outline three such groups: commuters, rural residents, and younger populations, specifically students in secondary and higher education. These populations are generally highly mobile, and for many of them e-bike adoption might form a healthy, pleasant and environmental-friendly alternative to current travel behavior for every day, non-recreational activities. We then discuss theoretical and methodological advances that may help shape future research on the advantages and limitations to e-bike adoption by these groups. Finally, we argue for an integrative approach to studying e-bike adoption to assess individual choice and behavior in relation to wider social and spatial contexts.

## THREE POTENTIAL E-BIKE USER GROUPS

In this paragraph, we discuss the potential for e-bike adoption by commuters, rural residents and students based on some group-specific advantages and limitations. We intend to offer a brief overview, rather than a comprehensive or complete review.

**TABLE 1 |** Potential advantages and limitations to e-bike use, summarized.

| | Potential advantages | Potential limitations |
|---|---|---|
| Commuters | Improve physical health | Less able to combine activities |
| | Improve mental wellbeing | Lack of parking and charging facilities |
| | Less costly than using car or public transit | Reducd comfort and ease compared to car |
| Rural residents | Cover longer distances | Distances may be too important |
| | Connect to public transit hubs | Lack of basic facilities such as bike infrastructure |
| | Offer flexibility over public transit schedules | |
| | More affordable than car or public transit | |
| Students | Independence from public transit schedules | Less affordable than bike or public transit |
| | Improve physical health | Stigma of "old-people-bike" |
| | Sustainable habit forming at a younger age | |

Some advantages, such as the environmental friendliness, and limitations, such as safety, may apply across groups, and are therefore not considered as group-specific factors here. The insights are drawn from findings from international academic literature and experiences and initial studies with e-bikes in the Netherlands. The group-specific advantages and limitations are summarized in **Table 1.**

## Commuters

Commuting is a cyclical and repetitive activity. Motorized commuting disproportionately contributes to congestion and pollution (Heinen et al., 2010). Commuting by active modes, however, can contribute to improved health and wellbeing. Enhancing the substitution of car commutes by more active modes have become a common focus of transport policies (Ogilvie et al., 2004). However, the effectiveness of such policies seems limited. In the Netherlands, for example, the average daily commuting distance is 24 kilometers in total, and 77% of the commutes is done by car (Statistics Netherlands, 2016). For car commuters who are unwilling to switch to biking, e-bikes may form a possible alternative. Below we list some possible advantages and limitations of e-bike use for commuting compared to car use.

### Advantages

- *Physical health.* Especially for commuters with a sedentary job, improving physical activity and health might be an important motivation for commuting by e-bike instead of car. Studies have shown that e-bike use positively contributes to health in sedentary lifestyles (Simons et al., 2009; Gojanovic et al., 2011). E-bike commuting also provides an easy way to incorporate daily moderate physical activity in busy schedules of working adults who find commuting by bicycle unattractive.
- *Mental wellbeing.* Workers often suffer from occupational stress and mental exhaustion. Research indicates that active travel modes like cycling that permit high levels of interaction with the outside world which may result in higher levels of mental well-being as compared with the car (van Wee and Ettema, 2016). Cycling, compared to driving, specifically offers more opportunities to enjoy and experience natural surroundings and scenery, which can lift people's mood and can help mentally prepare for or disconnect from work.
- *Affordability.* High purchasing prices, especially compared to regular bikes, form a barrier to e-bike use (Fyhri and Fearnley, 2015). Car and public transport commuters more likely have the financial means to buy an e-bike, or they might be eligible to contributions or tax incentives as part of work travel plans.

### Limitations

- *Combining activities.* The need for flexibility is a main driver for car use in western societies (Jeekel, 2014). Lower average speeds and reduced carrying capacity might make it difficult to combine e-bike commutes with other activities, such as bringing children to school, or attending meetings in different locations.
- *Facilities.* Safe bicycle parking at work is important in the choice to commute by bike, and affects the use of e-bikes as well (Popovich et al., 2014; Jones et al., 2016). Furthermore, a lack of charging facilities could restrict commuters' cycling range.
- *Comfort and ease.* Cycling has potential downsides compared to car travel regarding comfort and ease of use. E-biking may require special clothing and protection against weather (Lopez et al., 2017). Combining this with wearing a work uniform or suit might be considered problematic by potential e-bike commuters.

## Rural Residents

Lower densities of rural areas imply longer distances between activity locations, with a concomitant high reliance on cars and lower use of active modes. In many rural areas, car reliance is further reinforced by socio-economic changes that have led to a decrease in the provision of public transport and amenities like shops and schools (Pucher and Renne, 2005; Harms, 2008). Better insights in the potential advantages and limitations of e-bikes for rural mobility and accessibility can help policymakers to efficiently allocate rural transport budgets.

### Advantages

- *Distance*. Pedal-assistance makes it possible to bridge longer distances between activity locations in rural areas while requiring less physical effort (Fishman and Cherry, 2015).
- *Connectivity*. Lower densities can impede accessibility of bus stops and train stations. In the Netherlands, over 80% of the population lives within 7.5 kilometers of a rail station (Kager et al., 2016). An increased cycling range can enable easier access to transportation hubs, and expand available transport options.
- *Flexibility*. An e-bike can provide flexibility and independency (Jones et al., 2016), for example from bus and train schedules, which might especially be important in areas with lower-frequency transit provision.
- *Affordability*. Rural households make more trips by car compared to urban households, and more often own multiple cars (Pucher and Renne, 2005; Harms, 2008). Such expenditures can strain household budgets. E-bikes might form a cost-effective alternative to the purchase and use of cars.

### Limitations

- *Distance*. Rural residents travel longer average distances than urban residents, and more often rely on cars to do so. However, they also make less trips, and time spent traveling is mitigated by lower congestion and higher average speeds (Harms, 2008). Lower speeds and longer travel times are a potential barrier to e-bike use by current car and bus users in areas where distances between destinations are long.
- *Facilities*. Dedicated bicycle infrastructure is important to encourage bicycle use (Pucher and Buehler, 2008). This is especially true for rural areas where vehicle speeds are higher and heavy goods traffic is more important (Laird et al., 2013). Developing connected and fine-grained bicycle infrastructure networks in low-density areas requires significant investments. A lack thereof, and resulting incomplete, unsafe networks, might discourage rural e-bike use.

## Students

E-bikes increasingly appeal to a younger public. Peine et al. (2016) have termed this the "rejuvenation" of e-bikes. E-bike manufacturers have successfully designed and marketed e-bikes so that they have started to appeal to younger retirees, working adults, younger adults and children. A particular focus could be on students in secondary and higher education, who increasingly use the e-bike to travel to school or university.

### Advantages

- *Independence*. In many countries, children have increasingly become dependent on adults for their daily transportation (Frank and Engelke, 2001). Use of an e-bike could help them re-gain autonomy, for instance by enabling them to bridge longer distances to school (Nelson et al., 2007) by themselves.
- *Health*. Studies have stressed the importance of active travel for health in younger populations. E-bike use, instead of public transport or being driven to school, can contribute to better health (Davison et al., 2008).
- *Habit forming*. The role of habit in mode use is well established. Bike use in younger age can increase the likeliness of cycling in adulthood (Dill and Voros, 2007). Thus, e-bike use among students could set a standard for travel behaviors in later life.

### Limitations

- *Affordability*. Higher education students who use bikes or inexpensive student transit passes will likely find e-bikes expensive. For children and youth in primary and secondary education, possibilities for adopting an e-bike will probably depend on the willingness of their parents to buy one. Considering current purchase prices, e-bikes can reduce travel costs only if they avoid purchasing transit passes for several years in a row (Provincie Gelderland, 2016).
- *Image*. Although the evidence suggests that this is changing rapidly (Peine et al., 2016), e-bike use can evoke the stigma of "cheating" or being a bike for older or disabled people (Popovich et al., 2014; Jones et al., 2016).

# RECENT DEVELOPMENTS SHAPING TRANSPORTATION RESEARCH

More research is needed to verify our assumptions on the factors influencing adoption of e-bikes by commuters, rural residents, and students. Below, we briefly review two recent developments that have impacted transportation research, and provide a backdrop for studying e-bike adoption by new user groups: the behavioral turn in transportation research, and the mobilities turn in the social sciences.

## A Behavioral Turn in Transportation Research

Transportation studies have traditionally distinguished two pathways to more sustainable transport systems: technological changes aimed at mitigating negative impacts, and behavioral changes aimed at reducing levels of use (Hendrickx and Uiterkamp, 2001). The effectiveness of new technologies alone has been questioned (Steg and Gifford, 2005). In particular, it has been argued that potential decreases in greenhouse gas emissions due to use of new technology and alternative fuels would be counterbalanced by the growth of passenger travel in the developing world (Schäfer et al., 2009; Schäfer, 2012). Other problems, like urban sprawl and destination in-accessibility have broader causes for which technological innovations not necessarily form a solution (Steg and Gifford, 2005).

Doubts about the effectiveness of technological solutions have inspired a stronger focus on behavior and mobility management. According to Schwanen et al. (2012) this has become "something of a mantra" (p522) impacting political and intellectual agendas. In policy, this has resulted in mobility management through "soft measures" targeting individual behavior change. However, measures targeting the individual to achieve broader social change have been subject to critique (Barr and Prillwitz, 2014). Financial rewarding schemes and gamification, both examples of soft measures targeting the individual, potentially bring unintended or undesirable consequences (Te Brömmelstroet,

2014). Furthermore, it is increasingly recognized that people's travel behavior, like most daily behaviors, largely ensues from automatic processes or habits, which are altered by key events and long-term processes (Müggenburg et al., 2015). Daily mobility is thus formed at the intersection of both automatized sequences of behavior and more deliberate decision-making (Shaw and Hesse, 2010). Schwanen et al. (2012) argue for a focus on habit beyond cognition, to include the role of community, society, and other stakeholders than transport users in forming and breaking travel habits. To capture this complex set of relationships, research and policy must shift from a sole focus on individual behavior to a more comprehensive consideration of individual practices in social and economic contexts (Barr and Prillwitz, 2014).

## A Mobilities Turn in the Social Sciences

The call for more comprehensive approaches to study travel behavior can be located within a wider development generally referred to as the *new mobilities paradigm* in social sciences. This perspective broadens the traditional conception of mobility in transport studies, and provides a more theoretical and multidisciplinary engagement with physical, virtual, and imagined movement of people, objects and information (Hannam et al., 2006; Sheller and Urry, 2006). It considers mobility at different scales (small-scale bodily movement, global flows), taking into account immobilities ("moorings" underpinning mobility systems), politics of mobility, and bringing to the fore alternative, "mobile" methods (Hannam et al., 2006; Cresswell, 2010, 2012; Shaw and Hesse, 2010).

Recently, geography and transport geography have seen a surge of interest in mobilities, leading to a larger variety of philosophical and methodological approaches (Goetz et al., 2009). This seems a welcome development. For long, transport was considered so obviously fundamental to society that there was no need to explain how or why (Keeling, 2007). Transport studies focused on minimizing costs and maximizing efficiency by applying insights from economics and engineering (Røe, 2000). As Hanson (2003) argues, while human geography developed more critical approaches under social theory, transport geography remained stuck in the quantitative-analytic framework of the 1960's. Although others have disagreed (Goetz et al., 2009), there is general agreement that transport geography further benefits from alternative conceptualizations of movement as offered by the mobilities turn. Hence the argument for further bridge-building between the disciplines, where insights in the underpinnings, experiences or representations of transport and travel could further advance transport geography (Cresswell, 2010; Shaw and Hesse, 2010). For alternate perspectives to movement and travel, mobilities scholars have proposed the employment of mobile methods that focus on qualitative-critical analysis (Sheller and Urry, 2006). In general, however, it is argued that transport studies would benefit from balancing traditional quantitative-analytical and alternative qualitative-critical methods, and adopting mixed-method approaches (Goetz et al., 2009; Shaw and Hesse, 2010; Aldred, 2014). Examples of using mixed-methods in (e-) bike mobility research can be combinations of GPS-tracking, in-depth or ride-along interviews, video-ethnography, or survey research. Combining these methods can help contrast or complement findings to generate new insights.

Due to developments described above, transportation research is evolving to a more comprehensive and critical understanding of mobility, which can inform future inquiry into the development of e-bike mobility. Conceptual and methodological advances in mode choice and mobility behavior models reflect those described in the behavioral and mobilities' turns.

# STUDYING MODE CHOICE AND MOBILITY BEHAVIOR

## Modelling Mode Choice

Travel mode choice is an important aspect of mobility behavior. Psychological models to study decision-making have become more integrative. Traditionally, an important starting point was the theory of reasoned action (TRA) (Fishbein, 1967). It assumes that behavior is best predicted by intention, which in turn results from attitude toward the behavior and perceived social norm. The theory of planned behavior (TPB) (Ajzen, 1985) extends the TRA by adding perceived control over the performance of the behavior (Montano and Kasprzyk, 2008). Variations on TRA/TPB have been widely used to predict and explain mode choice behaviors (e.g., Heath and Gifford, 2002; Bamberg et al., 2003). However, in light of criticisms, alternative models have also been proposed. The Integrated Behavioral Model extends TRA/TPB to include additional components from other behavioral theories such as knowledge and skill, environmental constraints, salience of the behavior, and the role of habit (Montano and Kasprzyk, 2008). People's tendency to (unconsciously) conform to norms in performing pro-environmental behavior (Keizer and Schultz, 2013) spurred the development of models which place greater emphasis on norms, such as value-beliefs-norms theory and the norm activation model (Steg and Nordlund, 2013). The theory of goal framing suggests that behavior is guide by hedonic goals ("to feel better right now"), gain goals ("to guard and improve one's resources"), and normative goals ("to act appropriately"), and provides insights in how normative goals can be strengthened or weakened by environmental cues, like social norms.

Given that travel mode choice is often habitual, attention has also focused on ways to break routines. Strands of research have focused on changing situational context (e.g., temporary discounts on transit passes) and the role of life events (changing jobs, moving, child birth) (Chatterjee et al., 2013; Klöckner and Verplanken, 2013). These events are potentially powerful in changing travel behaviors. Properties of the transport mode in relation to the traveler's needs may also guide choices for a transport mode. The pyramid of customer needs provides an example of the latter approach (Van Hagen, 2011; CROW, 2015). This model ranks mode properties and subjective experience analogous to Maslow's hierarchy of needs. The model assumes that transport users choose a mode by evaluating the basic conditions for use (safety and reliability), dissatisfiers or factors

they expect to be met (speed, ease of use) and satisfiers that make the journey truly enjoyable (comfort and experience).

In sum, different models have been developed to conceptualize the role of deliberate decision-making, norms, habits, key events and mode properties in travel mode choice. This offers some practical cues on how to approach the study of potential modal shift toward e-bike mobility.

## Modeling Mobility Behavior

In line with the developments discussed, mobility behavior modeling has progressed from a rather narrow focus on trip generation to considering the role of perception and experience in mobility. Originally, trip-based approaches represented data in an origin-destination framework. A long-dominant analytical tool was the "four step model," which forecasted trip generation by contrasting demand (trip generation, distribution, modal split) and supply (the transportation network) (McNally, 2007). A common critique of this analysis was the lack of attention to behavior underlying these decisions. Approaches that considered activity behavior generating travel became known as activity-based approaches (McNally and Rindt, 2007). Activity based approaches consider travel to be driven by a collection of activities that form an agenda. Important in this respect was Hägerstrand's time-geography (Hägerstrand, 1970) and its study of individual behavior in relation to situational setting (Shaw and Hesse, 2010). Time-geography focuses on the constraints on human activities in space and time, which cause activities to occur at specific times and locations. It distinguishes capability constraints (individual or technological constraints to move), coupling constraints (the need to couple with others for given durations) and authority constraints (limitations of physical presence by public or private authority). Over time, others came to argue for the importance of including cognitive constraints (Kwan and Hong, 1998), which influence how the individual processes and acts upon information from his environment. Constraints are an important element in studies involving mobility and wellbeing in older age. "Life space" measurement is especially used to assess older adults' mobility by measuring the relationship between frequency and distance of travel using life space diaries. These diaries specify when, why, how and how often they travel to diverse destinations, starting from their bedroom outward (Peel et al., 2005), and give insight in the experienced restrictions to their everyday mobility. Such conceptions offer impetus to study e-bike use beyond a narrow focus on trip behavior, in an approach that pays equal attention to travel constraints and the organization of daily activities that result in certain modal choice.

# CLOSING COMMENTS

The rapid ascent of e-bike use represents a major development in transportation in recent years. Along with other forms of active and electric mobility, e-bikes form a promising and potentially critical component of the necessary shift toward more sustainable transportation systems. Depending on age, occupation, and personal circumstances of the user, but also spatial context, it seems that the e-bike can facilitate his or her mobility in several ways. We have outlined some of the factors that can both facilitate and constrain this use.

The magnitude of e-bike adoption rates in different countries around the world offers unique opportunities for transportation researchers to study more closely the mechanisms driving mode choice, modal shift, and associated changes in travel behaviors, among varied populations in different geographical contexts. It is our view that these studies should be considerate of developments in fields associated with or adjacent to transportation studies, including (but not limited to) behavioral and mobilities approaches as mentioned in this paper. By taking into consideration insights and findings from these approaches future studies on e-bike adoption by various user groups can benefit from approaches that combine, integrate and mix diverse perspectives and research methods, and in this way add valuable insight to the existing body of knowledge.

# AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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