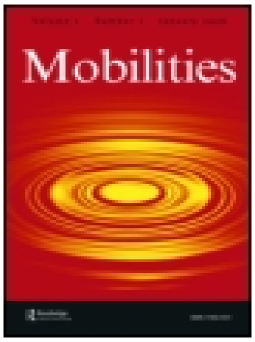

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ARTICLE

The rise of the e-bike: Towards an extension of the practice of cycling?

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ABSTRACT
E-bikes are bicycles with a battery-powered motor assisting the rider. With sales rising rapidly in many countries, e-bikes are likely to become a key component of a transition towards a low-carbon mobility. However, there is a scarcity of research into either the similarities or the differences between the practice of e-cycling and conventional cycling. The paper proposes a theoretical framework to address (e-)cycling based on the notions of motility (individuals' cycling potential) and bikeability (spaces' hosting potential). The framework is applied to a large-scale survey (14,000 bike commuters in Switzerland). The analysis shows that the e-bike makes it possible to overcome some of the barriers faced by conventional cyclists, such as distance, gradient and physical effort. The e-bike empowers more people to cycle, across social groups (women, couples with children, people over 40, people with a lower physical condition) and spatial contexts (suburban and rural areas). By reaching groups and spaces that are more motorised than average, the e-bike expands the practice of cycling as a complement or alternative to auto-mobility. However, both e-cycling and conventional cycling share many characteristics (e.g. motivations) and face similar challenges (in terms of a lack of infrastructures, etc.).

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Cycling; electric bicycle; e-bike; e-mobility; sustainable transport

1 Introduction

The e-bike is a bike with a battery-powered motor assisting the rider's pedal-power. The riders choose the level of assistance, which kicks in as they pedal and then decreases and stops when a certain speed is reached (25 km/h for the pedal-assisted electric bicycle or *pedelec*, the most common e-bike, or 45 km/h for the *speed-pedelec*). Since the mid-2000s, sales have been rapidly increasing.

This paper focuses on Switzerland, where the e-bike has been steadily growing in popularity. In 2006, e-bikes represented only 1% of the new bikes sold (3,200 units), but by 2019 this had increased to 36% (133,000) (Velosuisse 2020), while by 2015, 7% of Swiss households owned at least one e-bike (OFS, and ARE 2017). Record growth has been observed in most other European countries also. In the Netherlands – the country with the highest modal share of cycling – the majority of adult bikes sold are now e-bikes (Reid 2019), and the European Cyclists' Federation estimated in 2017 that 50 million e-bikes would be sold in the EU between 2018 and 2030, a prediction that has since increased to at least 150 million e-bikes by 2030 (ibid.).

The e-bike is part of the cycling renaissance. Despite its battery, it is one of the most environmentally friendly transportation modes, after walking and conventional cycling (Bucher et al. 2019;

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Fishman and Cherry 2016). Yet while it is likely to be an important component of a transition towards a low-carbon mobility, it is often overlooked in debates on e-mobility, which are usually monopolised by the e-car, despite the fact that the volume of sales of the e-car is much lower (Behrendt 2018).

This paper aims to understand better the practice of e-cycling and its differences and similarities in comparison with conventional cycling. The paper draws on the concepts of the system of mobility (Urry 2004), motility and hosting potential (Kaufmann, 2011) to conceptualise (e-)velomobility. In this theoretical framework, the use of the (e-)bike (in terms of cyclist profile and journey characteristics) is seen as resulting from the meeting point of individual cycling potential (access, skills and appropriation related to the bike) and the hosting potential, or bikeability, of territories (spatial structure, infrastructures, norms and rules). Here, mobility is regarded as an entanglement of movements, meanings and experiences (Cresswell, 2010) in a context of power, i.e. in the context of the dominant system of automobility. The paper, therefore, contributes to the field of mobility studies in its aim 'to explore social formations, practices, structures, meanings and politics of the mobile world' through the example of a new mode of transport and in the perspective of a transition towards a low-carbon mobility (Behrendt 2018, 64).

This paper is based on a large-scale survey of 14,000 bike commuters in Switzerland. It first addresses bicycle use, before looking at individual cycling potential and then at the hosting potential of spaces. E-cycling and conventional cycling are compared in order to identify how and to what extent the e-bike expands the practice of cycling. Results indicate that the e-bike presents an opportunity to overcome some of the barriers faced by conventional cyclists, such as distance, gradient and physical effort. Thus, the e-bike empowers more people to cycle and expands the practice of cycling to an increased range of social groups (including women, couples with children, people over 40 and people with a lower physical condition) and spatial contexts (suburban and rural areas). By reaching groups and spaces that are more motorised than average, the e-bike can be regarded as a complement or alternative to automobility. However, e-cycling and conventional cycling share many characteristics (e.g. motivations) and face similar challenges (lack of infrastructure, cohabitation with cars, etc.).

2 Theoretical framework

2.1 Addressing velomobility

Several authors have highlighted the importance of addressing cycling in a holistic way. Conventional models of transport planning and modal choice – based on minimising travel cost and time – are largely insufficient (Handy, Bert, and Kroesen 2014), since cycling depends on material conditions (urban forms, infrastructures) and takes on very different meanings with regard to periods of time, spatial contexts and social groups (Spinney 2009).

Some studies address these issues through the notion of cycling culture (Cox 2015). In countries with a mature cycling culture, such as the Netherlands, cycling is a ubiquitous and normalised mode of transportation. Other scholars view cycling through the lens of social practice theory, and analyse it as a combination of materials, competences and meanings (Spotswood et al. 2015; Watson 2013), while still others draw on the concept of the system of mobility. Taking automobility as an example of a system of mobility, Urry (2004) demonstrated that the car is much more than just a vehicle, but refers also to a socio-technical assemblage involving industries, infrastructures, rules, images, representation, etc. Other authors have applied the concept of the system of mobility to cycling with the term 'velomobility' (Behrendt 2018; Cox 2019; Koglin and Rye 2014; Spinney 2009; Watson 2013). However, they see velomobility as an incomplete system because it lacks dedicated infrastructures and social legitimacy in a context dominated by automobility. Indeed, automobility and velomobility 'compete for people's time, for road space, for resources, and in discourse' (Watson 2013, 121), and automobility still has an 'enormous competitive advantage in recruiting practitioners and sustaining performances' in many countries (ibid. 124).

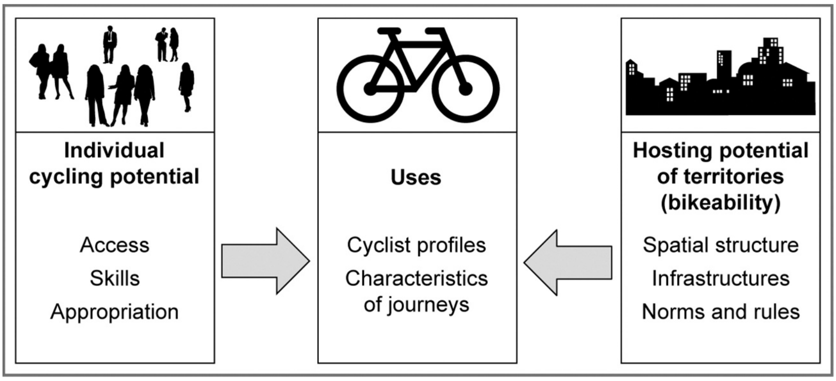

Figure 1. The dimensions of (e-)velomobility (source: author; images taken from pixabay.com).

Behrendt (2018) takes the idea of velomobility further, to suggest the idea of e-velomobility to refer to the 'practices, systems and technologies of electrically assisted cycling where velomobility's pedal-power combines with e-mobility's battery/motor assistance to propel the rider'.

This paper proposes to conceptualise (e-)velomobility, drawing on Kaufmann's three dimensions of mobility (Kaufmann 2011): (1) movements in physical space (in this case, uses of the bike), (2) the ability to move, or motility (the individual's cycling potential), and (3) the range of possibilities of a space – or the space's hosting potential for a practice (its bikeability) (Figure 1). This approach shares principles with the others mentioned above, such as the need for a holistic understanding of cycling. The advantage of this approach is that it enables the identification of the various mechanisms of the (non-)adoption of cycling at both an individual and a contextual level.

The first dimension of the theoretical framework – the use of the bike – covers factual elements that transportation studies traditionally address: the characteristics of the journeys (frequency, length, origin/destination, motives, etc.) and user profile (socio-economic status, gender, age, etc.). The extent to which the (e-)bike is used can be regarded as the meeting point of the cycling potential of the individual and the territory. These two dimensions are now discussed in the case of cycling.

2.2 Individual cycling potential

Individuals are characterised by their aptitude for movement, or motility, in a given physical, economic and social context (Kaufmann 2011, 37). This implies that mobility be thought of not only in terms of journeys but also of experiences, representations and the capacity to be mobile. It comprises three dimensions: access ('can'), skills ('know') and appropriation ('want') (ibid.).

'Access' refers to the mobility options available to an individual (depending on price, time, etc.) and equipment, such as vehicles (cars, bikes, etc.), public transport passes or subscriptions to car-sharing schemes. These can all be regarded as part of an access rights portfolio, which comprises 'all the instrumental resources which individuals get the right to use' (Flamm and Kaufmann 2006, 171).

Skills and knowledge are often underestimated in transport studies, although they are necessary in order to utilise any mobility offer. Riding a bike, for example, requires skills in five fields in addition to keeping one's balance while pedalling (Flamm 2004): the required physical condition, experience of concrete traffic situations, a good knowledge of the spatial context (in order to find a convenient route or avoid disruptions in the urban fabric, etc.), the ability to estimate the duration of the journey, and organisational knowledge in order to orientate oneself, to plan activities or to do necessary repairs. This last point refers to the notion of 'convivial tool', which Illich defines in his critique of the industrial system as a tool that enhances the 'independent efficiency' of its users and enables them to 'master' themselves (Illich 2009). Illich cites the mechanical bike as an example of convivial tool.

Appropriation, or enactment, defines the way in which individuals perceive and select mobility options according to their plans, aspirations and habits. The actual use of a transportation mode depends, among other things, on an individual's attitudes and perception of the various modes. Mobility can be conceptualised as a combination of physical movement (getting from A to B), meaning (representations, political claims, etc.), and embodied experience (Cresswell 2010). These dimensions may each represent motivations for or barriers to cycling (Rérat 2019).

2.3 Spaces' cycling hosting potential

For Kaufmann (2011), the hosting potential of a space refers to how receptive or suitable it is for certain modes of transportation. This receptiveness relates to the notion of affordance (Gibson 2014), which derives from the verb to afford, and connotes both provision or supply and ability to do something.[1] In the case of cycling, I define the hosting potential of a territory and its affordances as its bikeability,[2] which has three main aspects: spatial context, infrastructures, and rules and norms.

The spatial context refers to the topography and the weather conditions, and also – or more importantly – to the urban form. Density, compactness, functional diversity, the attractiveness of the landscape and the built environment along cycling routes are all factors that favour cycling (Handy, Bert, and Kroesen 2014; Pucher and Buehler 2012).

The hosting potential for the various transportation modes is also the consequence of power relations in space (as seen in the allocation of budget or surface) and of planning models (Koglin and Rye 2014). Modernist urbanism, influential mainly after the Second World War, promoted the separation of functional areas (living, working, recreating and moving about) and led to the marginalisation of cycling in planning. Transport infrastructures – for motorised traffic – were designed in what was thought a rapid and efficient way, with traffic flows segregated according to their speed. As a result, the street – the backbone of social life – had to give way to the road, where car traffic was to circulate without interruption.[3] More recently, however, cities experiencing a cycling renaissance have implemented alternative policies through measures such as traffic calming and networks of integrated bikeways (Buehler and Dill 2016).

Bikeability refers not only to infrastructures but also to immaterial and symbolic dimensions, such as the rules of the road and social norms. For example, the cultural meanings associated with the car (freedom, social status, etc.) have participated not only in the rise of the automobile but also in the decline of other modes (Urry 2004), since the car has informally privatised public space so that other users feel neither legitimate nor safe on the road anymore (Lee 2015). Thus where the bike is rare, it is less tolerated and is the target of negative attitudes, as the minority practice of cycling may be perceived as a critique of the dominant system of automobility (Prati, Puchades, and Pietrantoni 2017).

Affordance is relational in that it links the suitability of a context for a particular use with the intentions and capabilities of potential users. This paper proposes a theoretical framework that combines individual cycling potential with the bikeability of spaces at various levels to help explain why some individuals cycle and some don't,[4] or, in a biographical approach, why some continue cycling while others stop and yet others take it up again (Marincek and Rérat 2020, H. Jones, Chatterjee, and Gray 2014). This framework may also be used to interpret differences between cities, countries or periods of time. In this paper, the framework is applied in order to identify the similarities and differences between e-cycling and conventional cycling.

3 The literature on the e-bike

The literature on the e-bike is still rather scarce, although rapidly growing (Behrendt 2018). Research is still often based on an exploratory approach or on small samples of early adopters, and does not provide a systematic comparison with conventional cycling, as this paper aims to do. This literature review is organised according to the theoretical framework presented above, and focuses mainly on

Europe, as the literature in Asia and in the USA usually address electric bikes, which work without pedalling and are more like electric mopeds (Fishman and Cherry 2016).

The electric assistance may contribute to redefining some characteristics of the practice of conventional cycling. In terms of use, several differences are observed: 'the speed of the e-bikes reduces the time required to travel a given distance or increases the range of travel for a given amount of time relative to conventional bikes. E-bikes also accelerate faster than conventional bikes, and accelerating to and maintaining top speeds require less physical exertion' (Popovich et al. 2014, 39). Because of its 'combination of leg and battery power' (Behrendt 2018, 64), the e-bike could have an 'intermediator role' (Wolf and Seebauer 2014) or a 'transitional step' (Popovich et al. 2014) between conventional bikes and cars. Moreover, the electric assistance reduces the barrier of topography (MacArthur, Dill, and Person 2014, Johnson & Rose, 2015) and makes it easier for cyclists to travel further (Cairns et al. 2017; T. Jones, Harms, and Heinen 2016) including for utilitarian motives (Plazier et al. 2017).[5]

According to the research, the e-bike may enable more people to cycle, including some who could or would not otherwise make the same journey by conventional bike (Cairns et al. 2017; Dill and Rose 2012; Popovich et al. 2014). Several researchers have addressed the profile of e-bike users, although it has to be noted that differences may be due to the spatial context and the period of analysis, since early adopters may differ from newer ones. Men are more numerous than women in several studies (MacArthur, Dill, and Person 2014; Wolf and Seebauer 2014) although the opposite is also observed (Haustein and Mette 2016). Differences also depend on the type of e-bike, men being overrepresented among speed-pedelec users (Ravalet, Marincek and Patrick 2018). Retired people represent the majority of e-bike users in some studies (Wolf and Seebauer 2014), as the electric assistance makes it possible to go on cycling despite physical decline due to age (Leger et al. 2019), but in other studies, it is people in the second stage of their working life (40–65) who are overrepresented (MacArthur, Dill, and Person 2014). This may be because younger people are in better physical condition and/or because of negative perceptions of the e-bike (this will be discussed in more detail below). In terms of social class, e-bike users tend to have an above-average level of education and income (ibid.). This may be due to the price of an e-bike, as well as to the fact that those with a higher level of education are often observed among the early adopters of an innovation (Kapoor, Dwivedi, and Williams 2014).

In terms of skill, the electric assistance reduces the effort needed and is likely to facilitate cycling among people with a lower physical condition. It could also improve the extent to which cyclists feel at ease in traffic as it makes it easier to reach a higher speed and to accelerate quickly out of a stop sign (Popovich et al. 2014, 40). Yet the rising number of accidents is a source of debate as to whether the e-bike is more difficult to handle or whether the causes of the accidents are to be found in the lack of cycling infrastructures, the boom of e-biking or the fact that older people have a higher risk of serious injury (Götschi, Garrard, and Giles-Corti 2016).

The motivations for and barriers to using an e-bike may be similar to those found for conventional bicycles (Haustein and Mette 2016), but there are some differences related to electric assistance, such as the fact that it is possible to cycle despite steep gradients or long distances without sweating or feeling too tired, even for older people or those with a lower level of fitness (Dill and Rose 2012; Haustein and Mette 2016; MacArthur, Dill, and Person 2014; Popovich et al. 2014). It may also be easier to complete a succession of journeys (activity chain) or to escort children with a trailer or a child seat (T. Jones, Harms, and Heinen 2016). For couples, the e-bike may present a way of working out and cycling together, as it equalises the differences between physical conditions (Popovich et al. 2014). Health may be a motivation as well: e-cycling can satisfy moderate-intensity physical activity and generates health benefits (Gojanovic et al., 2011).

However, some characteristics of the e-bike may be perceived negatively. As they are more expensive than conventional bicycles, their owners may be more concerned about the risk of theft or the need for adequate storage conditions. They are also heavier and therefore more difficult to handle, and their extra weight may exacerbate 'range anxiety', which is the fear that the e-bike battery has an insufficient range to reach the destination (Popovich et al. 2014, 42).

E-bike owners are more present in suburban and rural areas than in cities (Ravalet, Marincek and Patrick 2018; Wolf and Seebauer 2014), which could be explained by the longer commuting trips. Conversely, in cities where the housing is older and denser, individuals may be dissuaded from owning an e-bike due to the lack of accessible parking space for these more expensive bikes.

As for regular bikes, cohabitation with motorised vehicles is a source of fear and danger (Popovich et al. 2014). On the one hand, crossroads and roundabouts could be potentially more dangerous for e-bikers because their speed may be underestimated by motorists (T. Jones, Harms, and Heinen 2016). On the other hand, the e-bike could be experienced as safer given its acceleration potential and the possibility of keeping a stable pace that would make it possible to circulate like a motorised vehicle (Dill and Rose 2012; MacArthur, Dill, and Person 2014). The average velocity of e-bikers differs significantly to that of other cyclists while riding uphill, and there seems to be a lower aversion of e-bikers to motorised traffic (Allemann and Raubal 2015).

Finally, in terms of social norms, the e-bike faces the same issues in countries with a low cycling modal share (e.g. in terms of legitimation) (Prati, Puchades, and Pietrantoni 2017). An additional feature for the e-bike is social stigma: it is associated with elderly people or with the idea that resorting to the electric assistance is 'cheating' and not 'proper cycling' (Behrendt 2018; Dill and Rose 2012; Leger et al. 2019; Popovich et al. 2014). Alternatively, however, riding an e-bike may be seen as choosing an innovative or technophile mode of transportation (Wolf and Seebauer 2014), which may help to overcome the social pressure of the car.

4 Methods

This paper's comparison of conventional and e-cycling is based on a large-scale survey carried out in Switzerland among participants in the 2016 Bike to Work campaign. In Switzerland, 7% of all journeys are made by bike (OFS, and ARE 2017). This is higher than in most English-speaking and Latin countries and lower than in Northern Europe (Pucher and Buehler 2012).

The Bike to Work campaign is organised by PRO VELO, the national bicycle advocacy association. Teams of four employees commit to cycling to work as much as possible in May and/or June. The formation of teams creates a motivational effect: regular cyclists encourage sport and leisure cyclists as well as less experienced colleagues to join in. Thus, the campaign reaches a variety of cyclists, attracting people already convinced by utility cycling and others interested in giving it a try.

Nonetheless, participants are not wholly representative of all people riding a bike due to self-selection effects: the campaign concerns utility cycling (and not leisure or sport) and employed people. A larger population (including children, teenagers and seniors) would, however, make comparison difficult (and in any case the first two do not have access to e-bikes due to age limit).[6]

The online survey was sent by the organisers (44,726 emails, 13,744 questionnaires were filled in for a response rate of 31%). The survey aimed first to provide an overview of utility cycling in Switzerland. The questionnaire was designed to address in detail the dimensions of velomobility – uses, individual cycling potential, and bikeability – mainly through closed questions, which were the same for both conventional cyclists and e-bikers. Informed by the e-bike literature, this paper compares their answers and evaluates how the electric assistance changes the practice of cycling. Statistical tests determine the significance of the differences.

5 Empirical results

According to the survey, 10,833 of the participants used a conventional bike, 2,141 an e-bike and 147 another type (e.g. folding bike, bike-sharing scheme).[7] This last category was removed, so that the sample is made up of 16.5% e-bike users[8] and 83.5% conventional cyclists. The analysis compares the two groups in terms of uses (profile of users, characteristics of journeys), individual cycling potential (access, skills, appropriation) and the territory's bikeability (place of residence and commuting journeys).

5.1 Uses

5.1.1 Profile of users

Several differences are observed in the profile of (e-)cyclists (Table 1). Women are more present among e-bikers (49.4%) than conventional cyclists (40.8%).[9] E-bikers are also older (75.9% are aged over 40 compared to 57.4% for other cyclists) and more likely to live in a couple with children (55.5% vs 43.9%). Compared with conventional bicycles, the e-bike has a wider audience in terms of both gender and life course (age and kind of household).

Differences regarding the level of income are small but statistically significant: e-bike users are slightly overrepresented among those with the lowest income (5.5% vs 4.1%) as well as the highest (17.5% vs 16.8%). In the first case, the e-bike may be an alternative to more costly means of transportation (a car or motorised two-wheeler), while in the second one it may be an additional mobility option.[10]

5.1.2 Characteristics of journeys

Commuting trips are considered both ways (both to and from work) in order to take into account topography and activity chains, and are found to last longer for e-bikers. Half of the users of a conventional bike spend 30 minutes or less on their commute, compared to only one-third of e-bikers, who are more likely to spend longer on their commute: 39.4% cycle between 30 and 60 minutes (vs 32.5%) and more than a quarter cycle for more than an hour (vs 19.5%). These journey lengths are globally quite long, which is partially due to Bike to Work (limited in time, competition, etc.). As we may expect that the extension of distances cycled concerns both kinds of cyclists, we can conclude that the e-bike is used less often for short journeys (to ride quicker) but more often to cover longer distances.

While three-quarters of the participants say that they cycle all year round, e-cyclists are more likely to reduce their practice (43.5% vs 33.2%) or to stop (26.5% vs 23.0%) when winter comes. The longer commuting trips and increased access to other transportation modes explain why e-cyclists are more affected by the season.

Finally, the bike is more often used for the whole commuting trip when it is electrically assisted (94.7% vs 87.5%), but much less for the first mile (from home to a station; 6.4% vs 12.7%) and the last mile (from a station to the work place; 2.0% vs 5.4%). This may be due to the larger range of e-bikes and to parking concerns for e-bikers outside the home and the workplace. Although e-bikes are heavier, there is no difference in how likely the cyclist is to take their bicycle onto public transport (about 2%).

Table 1. Profile of the participants.

Variable	Modality	% of conventional cyclists	% of e-bikers	Statistical test (chi square)
Sex	Male	59.2%	50.6%	$p < .001$
	Female	40.8%	49.4%	
Age	Under 25	4.4%	1.5%	$p < .001$
	25–39	38.2%	22.5%	
	40–54	43.5%	58.4%	
	More than 55	13.9%	17.5%	
Kind of household	Person living alone	16.3%	10.5%	$p < .001$
	One-parent family	4.0%	3.6%	
	Childless couple	27.0%	26.9%	
	Couple with child(ren)	43.9%	55.5%	
	Living with parents	2.7%	1.2%	
	Flat-share	6.1%	2.1%	
Level of monthly income	Less than 3,000 francs	4.1%	5.5%	$p < .05$
	3,000–6,000 francs	35.2%	35.1%	
	6,000–9,000 francs	43.9%	41.9%	
	More than 9,000 francs	16.8%	17.5%	

Table 2. Frequency of use of the bike.

Variable	Modality	% of conventional cyclists	% of e-bikers	Statistical test (chi square)
To do the shopping	Never	17.9%	17.4%	p < .001
	From time to time	34.5%	43.7%	
	Frequently	22.3%	22.1%	
	Most of the time	25.4%	16.7%	
To get to leisure activities	Never	12.8%	15.1%	p < .001
	From time to time	35.2%	45.1%	
	Frequently	28.9%	26.9%	
	Most of the time	23.1%	12.9%	
As a sport or leisure activity	Never	8.9%	11.9%	p < .001
	From time to time	27.8%	33.9%	
	Frequently	28.6%	31.8%	
	Most of the time	34.6%	22.4%	
To get to work	Never[11]	1.3%	1.0%	p < .001
	From time to time	18.9%	18.5%	
	Frequently	20.4%	26.7%	
	Most of the time	59.5%	53.8%	

Table 3. Frequency of use of modes of transport other than the bike to commute.

Variable	Modality	% of conventional cyclists	% of e-bikers	Statistical test (chi square)
Car (driver or passenger)	Never	49.9%	30.6%	p < .001
	From time to time	31.8%	39.0%	
	Frequently	10.5%	18.6%	
	Most of the time	7.8%	11.8%	
Public transport	Never	27.7%	33.8%	p < .001
	From time to time	40.0%	46.7%	
	Frequently	13.9%	12.4%	
	Most of the time	18.4%	7.2%	
Two-wheeled motor vehicle	Never	90.5%	87.4%	p < .001
	From time to time	6.2%	9.0%	
	Frequently	2.3%	2.5%	
	Most of the time	0.9%	1.1%	
Walking	Never	52.8%	66.1%	p < .001
	From time to time	28.8%	21.8%	
	Frequently	12.1%	8.8%	
	Most of the time	6.3%	3.3%	

Both kinds of cyclist state that the bike is the mode they use the most to commute (Table 2 and Table 3). A small difference is noted, however, between people who cycle most of the time (59.5% for conventional cyclists and 53.8% for e-bike users) and those who use a bike for more than every other journey (20.4% vs 26.7%).

E-bike owners cycle less frequently for reasons other than work (Table 2), such as doing the shopping (16.7% say they usually use an e-bike for this, compared to 25.4% for conventional cyclists), to get to leisure activities (12.9% vs 23.1%) or for sport or leisure purposes (22.4% vs 34.6%). These differences do not seem to depend on the type of bike but on life arrangements. E-bike users are more likely to live in suburban or rural areas, in a family and to be in the second stage of their career. Such features are known to increase car ownership (see below).

When they do not cycle to work, e-bike users are more likely to drive a motorised vehicle (Table 3), in most cases a car (30% use a car frequently or most of the time, which is almost 12 points more than conventional cyclists). This difference also concerns motorised two-wheelers, but only to a small extent. On the other hand, commuters who ride a mechanical bike are more likely to use public transport (32.3% do it most of the time or frequently, vs 19.6% of e-bikers) or to walk (18.4% vs 12.1%).

5.2 Individuals' cycling potential

5.2.1 Access

95.7% of the regular cyclists do not own an e-bike and therefore limit cycling to a strictly human-powered experience. The remaining 4.3% have access to both kinds of bike. They have initiated a transition towards electric assistance but still (mainly) use their traditional bike, at least to commute.

A clear majority (67.2%) of the e-bikers also own a mechanical bike. Their practice of regular cycling may decline and even be taken over by the e-bike. Finally, 32.8% of e-bike users do not have a mechanical bike. The survey does not provide information about how many of them gave up their mechanical bike or started cycling again after purchasing an e-bike.

Access to other modes (Table 5) is consistent with commuting practices (Table 4). Conventional cyclists rely more on public transport and are more likely to have a national or a regional public transport pass than e-bikers (17.9% and 12.8%, respectively, vs 10% and 9.1%). Although the great majority has a driving licence in both cases, e-bikers are much more motorised: 63.6% always have a car at their disposal and only 8.8% do not own a car, while half of conventional cyclists always have access to a car and less than a quarter never do. The difference here is not due to the kind of bike but rather to the fact that the e-bike appeals more to people who are more motorised than average: those older than 40, with children, in suburban and rural areas. Residential context plays indeed a crucial role: 37.7% of the urban respondents do not have access to a private car but only 12% in the suburbs and 4.7% in rural areas. They are, respectively, 39.9%, 56.3% and 62.3% to have always a car at disposal (the remaining having access to a car on request). These shares are lower that what is observed on the national level where 74% of employed people aged between 18 and 65 always have a car at their disposal (OFS, and ARE 2017), which also shows that (e-)bike reduces motorisation.

5.2.2 Skills

Skills have been addressed through how at ease cyclists feel in various situations (Table 6).[13] The level of ease cyclists feel varies greatly according to the kind of infrastructure and the level of cohabitation with motorised traffic; the proportions of e-bikers and conventional cyclists feeling at ease are closely related according to a linear regression ($R^2 = 0.978$).

Almost all cyclists are at ease riding on a cycle path (separated from motorised traffic). They are still a majority to be at ease in residential areas (where there is less, and slower, car traffic) and on roads with a 50 km/h speed limit and a cycle lane (delineated using paint on the road). The latter is still the more usual way to make room for cyclists in Switzerland, and yet 20% of cyclists still do not feel at ease (a proportion that would be much higher if children, teenagers and elderly were considered).

Table 4. Characteristics of commuting trips.

Variable	Modality	% of conventional cyclists	% of e-bikers	Statistical test (chi square)
Duration (both ways)	Less than 30 minutes	48.0%	33.0%	p < .001
	30–60 minutes	32.5%	39.4%	
	More than 60 minutes	19.5%	27.5%	
Seasonality	Only during warm months	23.0%	26.5%	p < .001
	All year round but more during warm months	33.2%	43.5%	
	The same all year round	43.8%	30.0%	
Commuting trip[12]	From home to work	87.5%	94.7%	p < .001
	From home to a public transport stop	12.7%	6.4%	p < .001
	From a public transport stop to work	5.0%	2.0%	p < .001
	Taking the bike onto public transport	2.6%	2.1%	n.s.

Table 5. Access to modes of transport.

Variable	Modality	% of conventional cyclists	% of e-bikers	Statistical test (chi square)
National pass	No	82.1%	90.0%	$p < .001$
	Yes	17.9%	10.0%	
Regional pass	No	87.2%	90.9%	$p < .001$
	Yes	12.8%	9.1%	
Motorised two-wheeler	No	86.9%	83.5%	$p < .001$
	Yes	13.1%	16.5%	
Car	No	22.4%	8.8%	$p < .001$
	Yes, on demand	28.0%	27.6%	
	Yes, always	49.6%	63.6%	
Driving licence	No	5.2%	2.4%	$p < .001$
	Yes	94.8%	97.6%	

Table 6. Extent to which cyclists feel at ease.

Variable	% of conventional cyclists feeling slightly/very at ease	% of e-bikers feeling slightly/very at ease	Difference
When riding on a cycle path (separated from traffic)	95.7%	95.2%	−0.5
When riding in a 30 km/h zone or in a residential neighbourhood	89.7%	85.6%	−4.1
When riding on a road with a 50 km/h speed limit and a cycle lane	81.8%	79.1%	−2.7
When riding on a road with an 80 km/h speed limit with a cycle lane	39.1%	40.9%	1.8
When riding on a road with a 50 km/h speed limit without a cycle lane	24.1%	20.7%	−3.5
When riding on a road with an 80 km/h speed limit without a cycle lane	5.7%	4.9%	−0.8
When riding through a roundabout	41.1%	38.5%	−2.5
When riding up a slope requiring physical effort	75.3%	65.0%	−10.3
When estimating the duration of a new route	62.3%	57.6%	−4.7
When performing minor repairs (e.g. puncture)	51.2%	38.5%	−12.6

The extent to which people feel at ease is generally lower among e-bike users, although differences are small, except when using a cycle lane on a road with an 80 km/h speed limit. The slightly higher proportion of e-bikers saying they feel at ease in this case may be explained by the presence of speed-pedelec users, but no difference is found in comparison with conventional cyclists when there is no cycle lane.

Navigating a roundabout is no easier for e-bike users (38.5% vs 41.1%), although they can accelerate more quickly. The difference between the two groups exceeds 10 points for physical conditions (65% vs 75.3%), indicating that electric assistance is not enough to make e-bike users as much at ease as conventional cyclists, but that it helps people with a lower physical condition to cycle. A difference of 10 points is also observed with regard to the ability to perform minor repairs, because e-bikes are more technologically complex.

5.2.3 Appropriation

Appropriation has been defined as the factors motivating or discouraging bicycle commuting. Motivations can be summarised into three categories (Table 7).[14] The first is well-being, which can be physical (exercise) and psychical (cycling for pleasure or to 'switch off'). The well-being of a journey gives it value in itself so that it is not seen as a wasted time. The second type refers to the independence provided by the bike (flexibility, freedom, saving time). The third is related to civic engagement (respect for the environment, social activism).

Motivations stated by e-bike users and mechanical cyclists are highly correlated (linear regression; $R^2 = 0.982$). Differences are below one percentage point for five items: exercise, flexibility and

Table 7. Motivations for cycling to work.

Variable	% of conventional cyclists who slightly/strongly agree	% of e-bikers who slightly/ strongly agree	Difference
To do exercise	97.9%	97.7%	−0.2
Pleasure (fresh air, landscape, etc.)	88.0%	92.6%	4.7
Flexibility, freedom	90.0%	89.1%	−0.9
Respect for the environment	88.7%	88.1%	−0.6
To take my mind off things, to switch off from work	79.7%	85.0%	5.3
Money saving	53.0%	53.8%	0.8
Time saving	61.1%	53.5%	−7.6
Positive image of the bike in my social or professional circle	41.5%	41.7%	0.2
Social activism	38.0%	35.5%	−2.5
No other satisfactory transportation mode for the trip	23.4%	25.3%	1.8

freedom, environment, saving money, and the image of the bike in the social and professional circle. There are only four variables where the difference exceeds 2 points: E-bike users are more likely to mention the pleasure of riding (92.6% vs 88.0%) and the opportunity to take one's mind off things and to relax (85.0% vs 79.7%), but less likely to answer time saving (53.5% vs 61.1%) or social activism (35.5% vs 38%). These differences do not seem related to the electric assistance but are explained by the fact that more e-bikers have access to a car and that they take it as a point of comparison. This explains why the experience of riding is more important for them, but they are less likely to see it as time saving, and also why they cycle to do exercise and in respect for the environment in the same proportion as conventional cyclists.

In terms of barriers (Table 8), half the respondents state that weather conditions may prevent them from commuting by bike. Comments in the questionnaire show very important differences of what kind of weather is concerned in terms of temperature, precipitation or daylight. Other barriers refer to logistical constraints (carriage of packages, activities before/after work) or safety issues (accident, theft, air pollution), while variables related to comfort appear less important (unwillingness to sweat, unsuitable clothes, physical effort).

Barriers are similar for both types of cyclists (linear regression; R^2 = 0.990). Differences are smaller than 1 point for seven items, including criteria for which the e-bike could have an advantage as it lessens the required effort (carrying goods, issues of sweating and clothing, physical effort due to the topography or distance, exposure to air pollution). A small difference is found in terms of risk of theft (e-bikes are more expensive, but this means that their owner is more likely to find a storage solution before purchase) and image. E-bike users are a little bit more sensitive to weather conditions (54.2% vs 52.3%), activities before/after work (41.0% vs 39.1%) and accompanying children (22.6% vs 20.9%), which may be explained by their longer commute and family situation. The same can be said for safety issues, which shows the biggest difference, with 4.2 points between the two groups: as e-bike users commute further and are more likely to live in suburban and rural areas, they are more likely to have to cohabit with motorised traffic at a high speed.

5.3 The bikeability of space

People living in suburban and rural areas are much more present among e-bikers (53.2% and 23.7% vs 43.3% and 13.8%), while urban dwellers constitute 42.9% of mechanical cyclists (vs 23.1%)[15] Table 9. The e-bike thus expands the practice of cycling in terms of the spatial context. Suburban and rural dwellers have to commute longer distances on average, for which the e-bike is more suitable. An additional reason that people in cities are less likely to own an e-bike may be that they face more problems in parking their bike due to an older and denser housing stock.

Table 8. Barriers to cycling to work.

Variable	% of conventional cyclists who slightly/ strongly agree	% of e-bikers who slightly/ strongly agree	Difference
Weather conditions	52.3%	54.2%	1.9
Carriage of packages and goods	47.3%	46.8%	−0.5
Other activities before/after work	39.1%	41.0%	2.0
Risk of accident, lack of safety	35.7%	39.9%	4.2
Risk of theft or vandalism of the bicycle	26.6%	25.4%	−1.2
Exposure to air pollution	23.2%	23.7%	0.5
Accompanying child(ren)	20.9%	22.6%	1.7
Other modes of transport more adequate	22.9%	22.1%	−0.8
Waste of time	19.2%	19.0%	−0.2
Unwilling to sweat or get messy hair	20.1%	18.8%	−1.4
Unsuitable clothes	18.4%	18.0%	−0.4
Too much physical effort required (hills, long distances)	15.4%	15.0%	−0.4
Negative image of the bicycle in my entourage	1.1%	1.5%	0.4

Table 9. Place of residence.

Variable	Modality	% of conventional cyclists	% of e-bikers	Statistical test (chi square)
Place of residence	Urban	42.9%	23.1%	p < .001
	Suburban	43.3%	53.2%	
	Rural	13.8%	23.7%	

The bikeability of the commuting trip (Table 10) shows that cyclists face safety issues. More than 70% estimate that the design of crossroads do not consider cyclists' needs, and more than 20% say that they cannot find enough cycle ways or paths (the majority may find alternative routes in residential areas or the countryside, cope with cohabitation with motorised traffic or benefit from cycling infrastructures).

A third say that they do not feel respected by other road users. Comments in the questionnaire show that this applies mainly to car drivers (right-of-way violation, close overtaking, etc.). Difficulties in cohabitation create a sense of insecurity among cyclists but also raise the issue of their legitimacy on the road. One out of seven cyclists does not feel safe on the commuting trip; this proportion is high given that commuters adopt strategies to avoid dangerous situations by taking alternative routes or by avoiding cycling at certain times of day (rush hour) or of the year (in winter when it is darker). It is also important to remember that the population does not include people who do not dare to commute by bike, or children, teenagers and the elderly.

E-bikers feel less safe (16.1% vs 13.5%) and less respected by other road users (36% vs 31.1%). Even though they are more likely to drive a car, they are more critical about cohabitation with motorised traffic. On the whole, electric assistance does not seem to help cyclists to cope with motorised traffic, although other factors may come into play, such as the length of commuting trips, the spatial context, age and gender. E-bikers are also more likely to wear a helmet (which is

Table 10. Experience of commuting by bike.

Variable	% of conventional cyclists who say no	% of e-bikers who say no	Difference	Statistical test (chi square)
Crossroads are designed to consider cyclists	70.5%	73.4%	2.9	p < .01
I find few dangerous zones/ crossroads	38.2%	40.0%	1.7	n.s.
I feel respected by other road users	31.1%	36.0%	4.9	p < .001
I find enough cycle ways/paths	22.9%	20.2%	−2.7	p < .01
I feel safe on the trip	13.5%	16.1%	2.6	p < .01

obligatory only for speed pedelec): 86.6% wear it most of the time and 4.7% never do so, while these figures are 62.4% and 16.2% for regular cyclists.

6 Discussion

This paper is based on a large-scale survey among 14,000 bike commuters in Switzerland, of which 16.5% use an e-bike. The paper addresses (e-)velomobility and conceptualises the use of a bicycle as the meeting point of the cycling potential of individuals and the hosting potential of spaces (bikeability). E-cycling and conventional cycling were compared in order to identify to what extent and in which ways the e-bike expands the practice of cycling. Such questions are important as sales of e-bikes might soon reach the number of mechanical bikes sold in several European countries. They are therefore likely to become an important part of future mobility systems.

In terms of profile, women are overrepresented among e-bike users in comparison to conventional cyclists. The fact that several studies found the opposite (MacArthur, Dill, and Person 2014; Wolf and Seebauer 2014) may indicate a diversification of e-bike adopters over time. People with a lower physical condition, as well as employees in the second stage of their working career, are more likely to adopt the e-bike (MacArthur, Dill, and Person 2014; Leger et al. 2019). However, this study shows that the e-bike is far from being restricted to these groups and is also used by younger and fitter cyclists, probably in order to cover longer distances (e-bikers cover on average longer commuting distances) or to transport children (parents are overrepresented among bike users).

E-bikes also expand the practice of cycling across spaces. While conventional cycling is prevalent in urban areas, it may be less attractive to suburban and rural dwellers, perhaps due to the fact that their average commuting journey is longer. Thus, the e-bike not only helps overcome the physical limitations of the user but also makes cycling a possibility for those living further from the workplace, enabling them to cover longer distances (A. Lee et al. 2015; Plazier, Weitkamp, and van den Berg 2017). It also appears that the e-bike helps to 'flatten' the topography, but the survey is not geographically precise enough to confirm this. While the cycling renaissance has mainly been observed in cities, it is interesting to note that the e-bike has the potential to widen this trend to other spaces.

On the whole, the survey shows that the electric assistance of the e-bike, by diminishing the physical effort required, improving the carrying capacity and increasing the potential distance travelled, empowers more people to cycle. It expands the practice of cycling across social groups (gender, age and life course position, physical condition) and spaces (suburban and rural contexts, distances).

Both practices share many characteristics in terms of individuals' cycling potential and the bikeability of commuting trips, although e-cycling is sometimes still perceived as 'cheating' (Popovich et al. 2014). Motivations relate to physical movement (going from A to B), meanings (images) and embodied experience (Cresswell 2010). It might have been expected that criteria such as respect for the environment, doing exercise or saving money would be rated lower for e-bikers, and time-saving higher. But this is not the case. This is explained by the fact that e-bikers are more likely to have a car and thus to compare cycling with travelling by car. Thus by reaching groups (couples with children) and spaces (suburban and rural areas) that are more motorised, the e-bike expands the practice of cycling as a complement or alternative to automobility.

Electric assistance or not, cyclists face common challenges in a country where utility cycling is still a minority practice. Cohabitation with motorised traffic may be difficult, and the absence of appropriate infrastructures and the lack of legitimacy of cyclists on the roads cause an important minority of cyclists to feel unsafe or disrespected by other road users. The level of ease of cyclists in various situations shows their sensitivity to cohabitation with motorised traffic and the need to either separate them or to reduce the volume and speed of cars. E-bikes do not compensate for a lack of infrastructure although they do enable users to ride at a more constant pace, including uphill, and to accelerate more quickly at crossroads. In fact, a slight effect to the contrary is observed, which may be explained by the profile of e-bike users (overrepresentation of women and higher age) and their commuting trips (longer and more often in suburban and rural contexts). The fact that they are more likely to drive a car and to know the motorised traffic does not make them feel safer.

The results and the theoretical framework of this paper provide a foundation on which to discuss a politics of e-velomobility in a world that is still car-centric. Extending velomobility across an increased range of social groups and spaces, the e-bike makes of cycling a stronger competitor of automobility that will play a key role in the transition towards a low-carbon mobility. However, several elements are required for an efficient and attractive system of e-velomobility. In terms of access, incentive programmes (such as subsidies) may trigger the purchase of an e-bike by a wider audience, and skills and appropriation may be enhanced through 'educational programs and outreach campaigns targeting groups for whom e-bikes could be especially beneficial' (Popovich et al. 2014, 43). Furthermore, if people are given the opportunity to experience the e-bike (through bike-sharing schemes or loans), this may overcome some perceived barriers.

Incentive programmes need simultaneously to stimulate demand (users) and supply. Supply refers not only to the industry but also to bike shops and repair services. One of the main differences between the e-bike and the mechanical bike is the level of technical complexity. While the bike has been seen as a convivial tool (Illich 2009) given the fact that users may repair it themselves, this is much less the case for e-bikes. This result highlights the need for services such as professional repairs to enable the development of the e-bike.

Measures regarding the hosting potential are crucial for the attractiveness of e-velomobility in terms of infrastructures (well-designed facilities, traffic-calming measures, etc.) and social norms. However, some specificities are yet to be considered. The e-bike widens the practice of cycling in spatial contexts (suburbs and rural areas, hilly territory) that have had much less experience of the cycling renaissance than urban centres. An implementation of cycling urbanism in these contexts could therefore lead to a diversification of cyclists as well as to a suburban and rural renaissance of the practice. Cycling infrastructures should also consider a bigger difference between cyclists in terms of speed and make it safe and convenient for cyclists to overtake. Marketing campaigns could also represent e-cycling as 'a normal part of the mobility landscape', to help overcome social barriers and stigma (T. Jones, Harms, and Heinen 2016). All of these elements would be part of building a system of (e-)velomobility.

In terms of research, the theoretical framework of (e-)velomobility based on the notions of individual cycling potential and the hosting potential of spaces provides an efficient analytical grid to address cycling (experience, skills, social meaning, politics, spatial organisation, etc.) that could be applied to and enriched by case studies in other contexts (including outside Europe). In terms of methods, each dimension of (e-)velomobility could be addressed with qualitative methods to deepen the meanings and experiences of (e-)cycling. Further research is also needed to analyse the evolution of e-cycling at a macro and a micro-level. At a macro level, the boom of the e-bike makes it necessary to analyse to what extent it will be adopted by other population groups, for other trips and in other spatial contexts. It will also be important to see whether the e-bike will replace the mechanical bike or redefine its practice, and to look at the way in which it will change the various dimensions of velomobility (Cairns et al. 2017). At a micro level, more biographical research is needed to understand when and why the e-bike is adopted (T. Jones, Harms, and Heinen 2016; Leger et al. 2019). In our sample, one-third of e-bike users do not own a regular bike and two-thirds do. Although no information is available on their respective use, it will be important to research to what extent both bikes are used, to consider whether the e-bike will progressively replace the mechanical bicycle and also to look at cases where the e-bike even enables a resumption of the practice of mechanical cycling. Such research is much needed, as the growing adoption of the e-bike, its cohabitation with the mechanical bike and its substitution of the car are key components of the transition towards a low-carbon mobility.

Endnotes

1 I use bikeability by analogy with the more widespread term of walkability (attractiveness of a space for walking). It does not refer to individuals, unlike the British initiative of the same name that promotes training programmes.
2 Affordance is a debated analytical tool in science and technology studies. Critics have highlighted the need to define and operationalise affordance, to analyse the underlying mechanisms and to account for the diversity of subjects and circumstances (Davis and Chouinard 2016).
3 Switzerland followed the same principles (adaptation of the city to the car, removal of many tram lines to make motorised traffic more fluid, etc.), but stands out as having invested in a very efficient train network. However, cycling was not integrated into transport planning and started to decline in the 1950s (De La Bruhèze and Veraart 2016).
4 See Geller's four types of cyclists (strong and fearless, enthused and confident, interested but concerned, no way no how), categorised according to their aspiration to cycle and their sensitivity to infrastructures (Dill and McNeil, 2013).
5 An important issue is the potential of the e-bike to reduce car journeys, although results differ regarding the extent to which the e-bike replaces trips that were formerly made by bike, on foot, by public transport or by motorised vehicles (Cairns et al. 2017; Dill and Rose 2012; Fyhri et al., 2017; Lee et al. 2015; Wolf and Seebauer 2014). The e-bike may also enable the maintenance of cycling against a backdrop of changing individual and household circumstances (Jones, Harms, and Heinen 2016).
6 The age limit for 25 km/h e-bike is 14 with a motorcycle licence and 16 without. The 45 km/h e-bike requires a motorcycle licence.
7 There are not many bike-share users due to the small size of Swiss bike-sharing schemes at that time.
8 No difference was made in the survey between pedelec (25 km/h) and speed pedelec (45 k/h) but the first type is largely majority (86% of the e-bikes sold in 2018).
9 This gender gap is partly explained by a lower participation of women in the labour market and a higher tendency to work part-time as well as the overrepresentation of men among sport cyclists who take part in Bike to Work. In Switzerland, 7% of men as well as women use the bike as their main mode of commuting (OFS, 2018).
10 On average, an e-bike costs three times more than a conventional bike (Velosuisse 2020).
11 The number of years of experience was not addressed due to the complexity of cycling trajectories (interruptions, frequency, leisure or utility cycling, etc.).
12 A principal component analysis reduced the number of variables and identified the components.
13 These results are based on a typology of municipalities – urban, suburban and rural – according to morphological (e.g. density) and functional (e.g. commuting) criteria (OFS, and ARE 2017). 'Urban' refers to large (above 100,000 inhabitants) and medium-sized (above 30,000) core cities, 'suburban' to the municipalities around these core cities (secondary centres of urban regions, inner suburbs that maintain continuity of the built environment with core cities, and also outer suburbs characterised by sprawl), and 'rural' refers to municipalities outside the predominant influence of core cities, notably in terms of commuting flows: small towns, agricultural municipalities, touristic municipalities, etc. This typology indicates the degree of urbanity (size, density, variety of urban functions) and influences mobility. Car ownership is higher in rural (88.4%) and suburban (83.7%) areas than in core cities (65.3%) (OFS, and ARE 2017). The share of motorised vehicles in the total number of trips logically follows the same trend (60.0%, 53.4%, 36.1%), while the opposite is found for public transport (7.7%, 12.7%, 19.2%), cycling (5.6%, 5.9%, 9.4%) and walking (25.3%, 26.6%, 34.1%).
14 Respondents could answer yes to more than one item, as they may change their behaviour according to the day of the week or the season.
15 These participants do not intend to cycle outside Bike to Work.

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